NOTES

ON

ELECTRIC RAILWAY ECONOMICS

AND

PRELIMINARY ENGINEERING

BY

illiam harles

W. C. GOTSHALL,

MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS, MEMBER AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, PRESIDENT AND CHIEF ENGINEER NEW YORK AND PORT CHESTER R.R. CO.

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PREFACE.

This book is based upon a series of lectures which I delivered at Lehigh University, last spring, the subject of which dealt with the economics of the preliminary and other determinations and of the construction and operating of high-speed and heavy traction interurban electric railroads. After the lectures had been delivered, some of the members of the faculty of Lehigh University and others who had heard the lectures, together with other men whose financial and other interests are essentially railroads, including practicing engineers, to whom the notes had been loaned, expressed the desire to have them published, for the reason, as they stated, that the treatment was novel and practical, and that no discussion of the subject, as presented in the lectures, existed in book form. I have, therefore, filled out the lecture notes, in some places adding matter thereto, and have rearranged the subjects so as to follow the order in which they would be taken up in the investigation and construction of an electric railway undertaking of the kind herein considered.

With the exception of a few large general maps, prepared for special cases, and some sets of railroad maps showing alignments and profiles, and a few sets of colored Progress Sheets, all of the full size original drawings and diagrams which I used while delivering the lectures have been reduced

and reproduced for this volume and appear at their proper places in the following pages.

Some time prior to the delivery of these lectures a series of hearings was held by the Railroad Commissioners of New York State to consider the application of the New York and Port Chester Railroad Company for a charter, and during this hearing the practicability from both an engineering and commercial standpoint of interurban high-speed electric railways was fully demonstrated. Although the New York and Port Chester Railroad is not yet in operation, I used considerable of the engineering and other data placed in evidence at this hearing, as well as much other data worked up in developing and demonstrating the commercial and engineering details of of the New York and Port Chester Railroad in the Lehigh University lectures, and have also employed some of the same data in this book.

Neither the lectures, or this book, were or are given as a treatise or exhaustive treatment of the subject as a whole, or of the details as indicated in the chapter headings. The lectures were intended to "point the way," and embody some of the results of twelve years of practice and application. This book is presented with the same object in view.

I desire to express my thanks to Mr. C. O. Mailloux, my associate, and to Mr. H. W. Blake, Editor of the Street Railway Journal, for the help they have given me in completing this book.

W. C. GOTSHALL.

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ELECTRIC RAILWAY ECONOMICS AND PRELIMINARY ENGINEERING.

CHAPTER I.

INTRODUCTORY.

The purpose of this book is not to discuss in detail the intricate electrical and other engineering problems connected with the location and construction of interurban electric railways. While a knowledge of such details is of great importance to the constructing engineer, indeed is essential to success, their consideration exceeds the proposed scope of this volume, and the reader is referred to the special, detail works on civil, electrical, mechanical, and steam engineering. It is the intention here to consider rather the subject broadly and as a whole, to outline the work of the electric railway engineer during the inaugurative and constructive period of a proposed road, and to give in a general way some bases upon which the costs of construction, probable present and future traffic, and ultimate economic results of the proposed railway can be gauged. In this discussion I will consider some of the technical details of interurban electric railroading which are not now to be found in the text-books, and will also, for the better understanding of the subject, take up certain concrete examples of the different subjects treated.

Success in the inauguration, construction, and operation of railways of the character discussed in these pages requires, on the part of the railway engineer, a combination of engineering and commercial skill. He must not only be conversant with those purely technical matters required of the civil and electrical engineer, but he must also be

thoroughly awake to and skilled in those commercial matters relating to finance, conditions affecting and governing the securing of business, retention of business, cost of handling a given volume of business, and the causes which influence and determine traffic.

The relations of the railway engineer to his clients are essentially fiduciary. His responsibilities are precisely those of trust company officers or trustees having in hand the investment of the funds of others. The engineer is expected to advise his clients whether the proposed enterprise will be a safe investment, and he is also expected to give the reasons for his conclusions. Upon his opinion and conclusions large sums will probably be staked, and for this reason he has no right to recommend any investment which will not pay either at once or in the near future.

The era of rapid transit, or high-speed electric roads, operated at such speed and headway of train units that people can live well beyond the congested commercial centers and daily pass between their homes and the commercial centers or places of their occupation or business without suffering the prohibitive loss of time and inconvenience entailed by the use of surface roads operating upon and along public streets and highways, is now here. Populations in our large cities have been increasing for years, but transportation facilities have, by no means, kept pace with the development. In consequence, the natural tendency to spread out over larger areas has been checked, as evidenced by the increase in the number and size of apartment and tenement-houses in our large centers of population during the past five or six years. Too much had been expected as a transportation agent of electric street railways. The actual demonstration of their speed limitations, as shown by their schedules, and rendered imperative by the paramount consideration of public safety, has developed:

First. The interurban railway operating upon public highways.

Second. The high-speed interurban railroads operating upon their own rights of ways, and, therefore, free to make the fastest practicable schedules.

Both of these have their province and both have come to stay. The latter, however, will undoubtedly have the greatest future and must receive that concentrated attention always accorded to an indispensable economic necessity, for such it certainly is.

The sun of the high-speed railroad, reaching out into the country, is now risen, but, as yet, is far from its zenith. The street surface or tramway systems will continue to do the short-haul business in the cities and other population centers for many years to come, while the suburban extensions of these lines will supply a service for those so close to the large cities that the element of time taken in the average trip does not figure as a very large factor. Both classes of road will soon be commonly recognized as feeders to the high-speed trunk lines and systems. Each will be a necessary adjunct of the other. The sun of the street surface railway is well beyond its zenith and while some development may be expected in the suburban or rural railway on public highways, its future is more or less limited. In the matter of those transportation prerequisites, viz., *speed* and *comfort,* neither class of road can offer much more than it is now giving on account of conditions not within its control.

At the present time, the determination of railway projects is essentially along the lines of heavy traction and interurban development. The latest projects, both existing and proposed, of interurban electric railway installations involve not only features entering into their preliminary determinations, but features of construction and operation differing from those which have heretofore been controlling factors in electric railways.

It is my purpose in this discussion to devote considerable time to the investigation of preliminary conditions, as well as to the determination of those characteristics of construc-

tion and operation which should be followed in the highest class of interurban electric railway projects.

In approaching this subject, it will be taken up in the following order:

I. Preliminary Determinations. (Chap. II–III.)

(a) First or preliminary determinations of the probable revenue and the general investigation of the physical characteristics of the territory proposed to be served.

(b) Investigation of the commercial and other characteristics of the territory proposed to be served.

(c) Preliminary surveys and fixing of preliminary lines and data on which to base relative and ultimate determinations.

(d) Prerequisites in connection with preliminary field work.

II. Location of Line and Engineering. (Chaps. IV–VII.)

(a) Controlling considerations, such as connecting centers of population, alignment and gradients, termini and stations, and prerequisites for high speeds and safety of the public, etc.

(b) Making of paper locations of probable routes, showing approximate line and profile of each route.

(c) Estimates of cost of superstructure, etc.

(d) Determination of cost of equipment. Preliminary plotting of schedules for the purpose of ascertaining approximate details of equipment.

(e) Determination of probable gross earnings.

(f) Determination of fixed charges and cost of operation and maintenance upon schedules as proposed.

III. Final Engineering Work. (Chaps. VIII–XVI.)

(a) Final consideration of the details of construction of superstructure, and details of engineering, such as power stations, rolling stock, etc.

(b) Securing right of way.

(c) Necessity for the provision of specifications clearly defining required conditions.

(d) Remarks on what specifications should be; that is, specifications should be drawn to specify, essentially, performance, and should only incorporate details of manufacture where there are several methods of obtaining the same object, one or more of which are recognized as better than the others.

(e) Remarks about construction.

(f) Most propitious time for starting of any new road.

IV. Operation and Management. (Chaps. XVII, XVIII and Appendix.)

(a) Organization of operating department.

(b) Economic considerations governing the construction of an electric road.

(c) Specifications for a moderate-sized and high-speed interurban railway.

CHAPTER II.

PRELIMINARY OFFICE DETERMINATIONS.

The original idea to connect two or more centers of population by an electric railway generally originates in the fertile and never-tiring mind of one or more promoters. A promoter is a prime mover of civilization. Before the promoters have proceeded far, however, they recognize the necessity for competent technical advice and assistance, with the result that an engineer is employed.

The first duty of the engineer should be to make a careful, although general, investigation to determine approximately the probable income or business of the proposed road, for the purpose of advising his clients whether to proceed and incur the relatively large expenses which further and especially a conclusive investigation will require.

In order to determine this question, he should have recourse to the United States census reports, as well as to such school and other local census reports as he can obtain. Once in possession of these population statistics, he should next ascertain the general characteristics of the population centers, that is, are they of the manufacturing, mining, agricultural, or other variety? All of the foregoing can be secured without visiting the proposed location, by having recourse to the statistics just referred to and by questioning the originators or promoters of the road.

The next recourse should be to existing statistics relating to populations, as nearly similar as possible to those under consideration. Such statistics show:

First. The population tributary to the line of road per mile of road.

Second. The rides per capita per annum.

Third. The receipts per capita per annum.

Fourth. The receipts per mile of road per annum.

In making such comparisons care should be taken to select

not only roads similar to the line proposed in length, character of equipment, and tributary population, but also in such local conditions as will affect the riding per capita and per car mile. Thus manufacturing communities will naturally be found to show a larger number of rides per capita than those of equal population where the pursuits are of an agricultural character. Difference in the "riding habit" will also produce large variations in statistics from cities or towns which otherwise seem sufficiently similar for purposes of comparison.

Table I below contains some statistics of the kind referred to:

TABLE I.

Approximate Earnings, Etc., for Different Interurban Populations.

CASE NUMBER.	Tributary Population.	Population per Mile of Track.	Gross Earnings per Mile of Track per Annum.	Gross Earnings per Capita per Annum.	Miles Single Track.	Times Population Carried.
1	120,000	1,764	$8,008	$4.54	68	92
2	18,000	1,200	5,478	4.56	15	85
3	60,000	1,463	5,216	3.61	41	....
4	120,000	732	4,000	5.46	164	....
5	24.500	1,114	4,400	4.00	22	....
6	98.000	1,750	14,000	8.00	56	162
7	21,500	935	10,500	11.23	23	115
8	275,000	1,100	7,600	6.91	250	130
9	54,000	1,200	3,600	3.00	45	54
10	81,000	1,884	3,100	1.64	43	83
11	53,000	1,205	4,800	4.00	44	75
12	36,000	667	3,300	4.98	54	99
13	60,000	2,857	7,000	2.45	21	54
14	79,000	1,197	6,400	5.34	66	121

In the foregoing table is shown some statistical information, computed from data at hand, of interurban roads now actually operating for a sufficient period of time to make the data reliable. This table, or one like it, can very profitably be used in the preliminary or office determinations of the engineer, entered upon for the purpose of ascertaining whether the proposed road possesses sufficient merit to war-

rant proceeding with the subsequent and costly engineering work.

Cases Nos. 3, 4, 5, 7 approximate nearly the conditions of the high-speed roads. The other cases are those of the high-class interurban roads built upon public highways, the average schedule speeds of which are between 10 and 16 miles per hour. The schedule speeds of 3, 4, 5, 7 will average nearer 20 miles per hour. Cases Nos. 9 to 14 are for groups of roads in one of the New England States.

It is impossible to give generally the minimum paying population per mile of track because, evidently, this varies according to local conditions and is also being decreased as a result of changing conditions and constant and more marked use of railways by the public. As a rule it might be said that a tributary population of from 500 to 700 per mile of track will constitute the minimum, although there are cases where a fairly profitable traffic has been built up, in connection with freight transportation, on a basis of 400 inhabitants per mile of track. In calculating population tributary to a road radiating from a large city, it is not customary to include the total population of this terminal, otherwise a road with scarcely any population outside of the large city would make a magnificent showing of population per mile of track.

The effect upon the traffic of an interurban system, due to a large city being situated at one of its termini, will undoubtedly be considerable, on account of the facility afforded by high speed railroads for the distribution of urban populations along its lines. The latest installations of high-class interurban railroads have already demonstrated this readiness of urban populations to spread out where proper transportation facilities exist. In estimating upon earnings, etc., for a proposed system I have always found it safe to take as a tributary population to the proposed road, that which is to be found within one-quarter mile to three-quarters of a mile on each side of the line of the road. This practice has been adhered to where the road passed through parts of large

cities and had a terminal in such large city. The engineer must also not lose sight of the fact that relatively high-speed interurban roads have at times completely altered the distribution of populations in and about cities and will probably do so to a greater extent in the future on account of recent improvements in the direction of increased safety, comfort, and speed. Generally speaking, such systems should be credited with the tributary population between and of their termini within one-quarter mile to three-quarters of a mile on each side of the road in making estimates, etc. This is, of course, on the assumption that there exists no like road at the time serving the territory properly or improperly, but where other transportation facilities, such as possibly steam or street surface electric may exist. Again, large termini have proved invaluable supporters of pleasure and general recreation business.

It is also important in making comparisons between two properties to follow the same method of obtaining population along the line. Thus, it is manifestly wrong to take the 1900 census in one case and count only the population of the incorporated towns and villages reached by the road, while in another case to take the latest local estimate and add to it the rural population within five or ten miles on each side. It is also a notable fact that the less the population per mile of track the greater will the earnings usually be per capita. In other words, a system operating through a number of large towns will not get as much business from each person in those places as it will per capita from the inhabitants of smaller towns.

Practicing railway engineers should and generally do have most extensive statistics of this kind. Those in Table I relating essentially to interurban roads are given partly for the purpose of indicating the form in which such statistics can be compiled, and partly to show how greatly the results from properties differently situated vary. Any figures of this kind to be reliable should indicate the latest obtainable data and these obviously are best attainable from periodical publications. It might be said here that the

annual reports of the Railroad Commissioners of the states of New York, Massachusetts, and Connecticut as well as the census report on street railways and such financial annuals as are devoted to street railway statistics, are invaluable for detailed statistical information of all kinds relating to the railroads which they contain. Too much emphasis, however, cannot be laid upon the unwisdom of drawing specific conclusions from the results derived from roads operating under entirely different conditions. Table II gives some statistics for interurban railways for the year ending June 30, 1902:

TABLE II.

Traffic on Different Interurban Railways.

	Miles of Track.	Fare Passengers per Mile of Track.	Fare Passengers per Car Mile.	Fare Passengers per Car Hour.
Elgin, Aurora & Southern	62.96	86,181	8.14	29.18
Union Traction, Anderson, Ind	150.06	64,777	2.56	[illegible]
Lewiston, Brunswick & Bath	56.18	75,419	4.04	[illegible]
Lexington & Boston	87.04	72,659	2.95	....
Old Colony Street Railway	879.26	122,187	4.98	45.71
Boston & Northern	440.88	157,868	4.90	44.45
Northampton & Amherst	14.84	68,052	8.46	80.74
Detroit, Ypsilanti & Ann Arbor	91.42	21,265	1.30	37.59
Grand Rapids, Grand Haven & Muskegon	52.68	11,212	1.34	[illegible]
Grand Rapids, Holland & Lake Michigan	69.00	12,464	1.19	[illegible]
Houghton County Street Railway	22.16	141,847	5.55	40.32
Southwest Missouri Electric Railway	86.61	68,287	2.62	....
Albany and Hudson Railway & Power	44.50	23,720	1.72	....
Hudson Valley Railway	184.10	81,670	2.82	....
Rochester & Sodus Bay	47.54	88,766	5.18	....
Cincinnati, Dayton & Toledo	78.85	49,961	1.87	....
Cleveland, Elyria & Western	76.50	30,017	2.04	26.58
Cleveland, Painesville & Eastern	48.26	[illegible]	1.84	....
Northern Ohio Traction	110.25	78,818	8.10	....
Dayton, Springfield & Urbana	55.60	6,537	2.00	....
Dayton & Troy	46.70	15,632	1.03	16.71
Lake Shore	188.41	20,102	1.59	22.62
Youngstown-Sharon Railway & Light	42.25	75,574	8.60	....
Lehigh Valley Traction	148.81	94,849	8.74	81.16
Altoona & Logan Valley	27.50	173,065	4.02	88.80
Conestoga Traction	88.81	59,276	8.30	88.12
Pittsburg, McKeesport & Connellsville	56.00	80,497	8.55	....
Wilkesbarre, Dallas & Harvey Lake	16.50	55,577	5.56	69.79
Northern Texas Traction	61.70	89,717	2.46	13.32

This investigation of probable traffic will be considered more in detail in Chapter VI. Its treatment at this time is only general and for the object only of reach-

ing a rough approximation of the future earnings of the road. With this in mind, and with the population and its distribution before him, together with the approximate length of the proposed road, it is a matter of simple mutiplication and division for the engineer to approximate the future traffic on his proposed road.

For instance, suppose a number of centers of population or towns represented by the points A, B, C, D, E, F, are located along a line.

Let

$P =$ total population tributary to line of proposed railroad.

$L =$ approximate length of proposed railroad between termini.

$A =$ receipts per capita per annum for approximately similar population and conditions.

$M =$ receipts per mile of road per annum for approximately similar population and conditions.

Then we have

$A \times P =$ probable gross receipts on per capita basis.

$M \times L =$ probable gross receipts on basis of population tributary to proposed line.

$\frac{P}{L} =$ tributary population per mile of line of proposed road, which should be compared with that of successful existing installations.

$\frac{A \times P}{L} =$ probable gross revenue per mile of the proposed road, which should be compared with the results of approximately similar enterprises, as shown in such statistical data as Table I.

The probable gross earnings together with a knowledge of the probable total cost of the road obtained by multiplying the length of the proposed road in miles, by the known approximate cost per mile of road of similar enterprises, which information will be found in the chapters on Track Construction, Power Stations, etc., will determine whether the

project is of sufficient merit to warrant proceeding further with it, that is, it will show roughly whether the relations between probable business and probable total cost are such as will probably produce a proper return upon the investment probably required.

It is in these preliminary matters and determinations that the value of conservative, experienced, and conscientious engineering and railway engineers is realized. A competent railway engineer will advise at once whether the enterprise is worth proceeding with and expending the considerable amount of money which will be required for the subsequent engineering work.

Granting that these preliminary conclusions are favorable, the engineer next proceeds to inform himself about the physical and more detailed characteristics of the proposed road and territory. The first step in this direction is to secure the best maps of the territory, such as those published by the United States Government and the various states, cities, towns, and counties which will be served by the proposed road. The maps of the United States Coast and Geodetic Survey are invaluable for use in connection with these preliminary determinations. These maps show contours and are generally quite accurate. By using them, a proposed line can be roughly sketched in and an approximate line and profile obtained from the contours, which can be checked by the use of such county and other maps as may be accessible. These maps can also be used with advantage by the preliminary surveying or field parties, which will be referred to in the next chapter.

CHAPTER III.

PRELIMINARY FIELD SURVEY.

We have assumed, now, that the engineer has carefully compared the data supplied by the promoters with all local and other sources of information which are available without a personal visit to the locality, and that his office determination is such as to be generally favorable to the construction of the road. We also assume that he is supplied with maps of the locality and a roughly approximate line and profile sketched on the general map mentioned in the last chapter. He is now in a position to make a personal inspection of the territory.

He should start at one of the termini and visit each of the population centers in person, noting, carefully, the characteristics of the people, the character of the population, the number and kind of the industries, and their probable stability. As this last consideration is ordinarily somewhat difficult to determine, it is best to obtain it by consulting the local bankers, who are readily and easily approached through the medium of introductory letters from bankers among the engineer's business connections or associates at his place of business.

Careful attention should also be paid on this personal reconnaissance to all existing recreation points, that is, picnic grounds, and other resorts which are likely to promote traffic. If none exists, the engineer should note where it would be possible and best to locate and develop them and estimate their probable cost, as well as the probable support which such a resort or resorts would receive. The recreation business of any railroad is a most important branch of its business. All of the revenue derived from such sources may be said to be almost entirely profit, as such additional revenue is obtained at a relatively insignificant cost for doing the business. Recreation resorts along the lines of a great many

railroads are the buoys which have for many years saved them from financial shipwreck. The importance of recreation resorts will be better appreciated when it is remembered that they attract traffic from probably the first of June until the first of September in northern climates, and much longer in southern climates, and that in conjunction with adequate and cheap transportation facilities, they afford practically the only relaxation for by far the major portion of every population, that is, the working men and women and their families.

After the preliminary office work, already described, has been done, the engineer should take no data which he himself has not verified as the basis for any conclusion. He now has the entire responsibility to bear. His report will be the basis for all the subsequent operations of the syndicate or company.

The collateral obligations of the company issued to provide money to construct the road will be subscribed to and sold largely upon his report as a basis or foundation. Promoters, real estate speculators and town boomers will paint eloquent portraits of the marvelous stability, development, and Aladdin-like characteristics of the territory proposed to be served by the road. It may do no harm to listen to such eloquence, but none of it should be allowed to creep into the report until it has been fully checked and verified, if a verification be possible.

The object of the engineer's inspection, in addition to the above, is to make a preliminary rough survey or reconnaissance of the proposed route which shall form the basis for the running of the preliminary location lines by the field parties or surveyors who will follow him. For this purpose the engineer should take with him a few portable field instruments, by the use of which he will determine approximate lines, directions, elevations, and conditions. The instruments commonly used for such purposes are a portable compass, and hand-level or clinometer.

To do this reconnaissance work conscientiously the engineer should *walk* over the possible routes. The word *routes* is used because the reconnaissance should develop several possible routes for consideration. A careful study should also be made of all possible routes *through* the various towns, cities, or other population centers. This detail cannot be too strongly emphasized. There is not the least doubt that disregard of the convenience of the public, by locating a line and stations at inconvenient distances from centers of populations, has been the cause of the unfortunate culmination of more railroad enterprises than all other causes combined. This does not mean that the line must necessarily be located and constructed through the centers of existing cities or towns. As a matter of fact such a plan might and very probably often would load an enterprise with such a heavy burden of fixed charges as to make failure a certainty from the outset. A good practice is not only to locate as near an existing center of population as possible, that is always well within the suburbs, but also along a line which will, on account of the development of the locality, be well through a center of population within a given period, say three or five years after commencing operation.

The engineer should always remember that railroads are built for the convenience of the public, and that the revenue of such enterprises will be an essential function of the conveniences afforded. Transportation is a marketable commodity, the value of which may be made very great, or relatively nothing, as the public convenience is catered to or neglected by locating its route and stations so as to facilitate the public convenience, or in disregard of it. The best route, as regards alignment and grades, may be the worst possible route from a commercial standpoint.

Railroads have been built which were technical engineering ideals, and whereon the cost of operation per car mile, or per ton mile, would have been ridiculously low for

a fair volume of business. But, on account of lack of business, due to a disregard of fundamental requisites, the roads were lost to the original owners and passed into the hands of others, under such conditions that they could be made part of some connecting or adjoining systems, and be held until the requisite business for the proper maintenance could be developed. It is well always to bear in mind that every business must be planned to pay, and that a railroad is no exception to the rule. In fact, on account of the nature of its business, that is always having a supply in excess of the demand, in other words, an average carrying capacity in excess of the passengers carried, it is a most exacting case demanding the highest engineering and commercial thought, sagacity, and consideration.

When the engineer has concluded his personal reconnaissance, he will have, in addition to a personal knowledge of the cities, towns, and other population centers, determined upon two or more probable routes, each of which is to be investigated by the subsequent surveying parties, for which matters are now ready.

The preliminary locating party is generally composed of the following:

1 chief of party.
1 transitman.
1 recorder for the transit measurements.
2 flagmen or chainmen.
1 leveler.
1 recorder for the levels.
1 rodman.
1 topographer.
1 topographer's assistant.
2 laborers to clean any brush, etc.,

or twelve men in all.

The chief of the party should, and generally does, accompany the engineer in making the preliminary reconnaissance.

The preliminary locating corps commences at one of the

termini and determines or runs two or more routes, establishing the line with the transit, and taking the levels at the same time. The topographer follows the leveling party, taking the elevations as they are marked on the stakes at intervals as a basis, and sketching in on his map the characteristics of the territory on each side of the transit line. The map on which he works shows as yet simply the line and transit stations and is prepared the night before from the observations of the transit and level parties of the preceding day, as explained below. The topographer indicates on this map:

1. Contours for each change of elevation of five feet.

2. Location and kind and approximate value of buildings and other structures on each side of the transit line.

3. Character of surrounding soil, that is, whether the appearance indicates rock or earth; character and stability of all slopes.

4. Courses and characteristics of streams and water-ways.

For this purpose the topographer carries with him a hand-level, portable compass, and a fifty-foot chain. The hand-level easily determines the elevation and contours very closely, by taking as the height of the instrument the eye, which is generally about five feet, and noting with the other eye where the sight-line through the hand-level strikes the soil. This distance is then measured with the tape, and sketched in and then noted on the sheet held on the portable drawing-board carried by the topographer. This portable drawing-board is about 24″ x 18″ with adjustable rollers mounted on two opposite sides. The sketch, prepared the evening before from the transit and level notes of the preceding day's work, is adjusted on these rollers and unrolled as the topographical party progresses. The distance on each side of the transit line to which the topography should be taken and shown varies with circumstances. As a rule it will be found sufficient to take data for 500 feet on each side of the center line. In a case where both

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sides of a ridge possess advantages, it may be taken for 1,000 feet on one side and 500 feet on the other. The taking of the data for 1,000 feet or more on one side often obviates the necessity of running a second preliminary line for part of the distance, practically paralleling the base line on which the topographer has worked during the first survey.

The chief of the party, as well as the transitman and leveler, should always make careful mental notes of everything along the line.

The day's work should always be plotted on cross-section paper, in duplicate, each night. The transit and level notes should also be transferred to another set of field-books each night. One of these sets of records is kept in a safe place at the base of operation, generally the hotel or inn. The other is carried into the field. The object of duplicating the records is to avoid the unfortunate and always expensive consequences which the loss of field-books and records involves.

It is while these preliminary investigations and surveys are in progress, and which will form the basis for the subsequent detail investigations and surveys, that attention should be paid to those all-important matters of alignment and grades. Long tangents should be sought for, and when curves are necessary, their actual length should be made as short as possible, having regard to the proposed schedule speed. In this respect electric road construction differs from that of steam railroad practice, as steam railroad engineers, as a rule, favor long curves. The principal reasons for the difference are two in number, viz.:

The electric road operation will be in shorter train lengths, hence, conversely, the headway will probably be shorter and there is greater reason for a clear view ahead. All curves cause an appreciable loss of time. No competent motorman will take such chances as would be involved in operating a train around a curve at fifty or sixty miles an hour on a short headway service, with the view ahead of

him obstructed for any considerable length of time. The other reason is that the speed of the electric train is better under control than that of the steam train. It can consequently quickly accelerate to full speed after passing a curve and make far better average time than on a line built for steam traction with long curves and short tangents. The object of the engineer should therefore be to get the car or train on the straight track or tangent as soon as possible.

As an illustration of the effect of introducing long curves may be cited a recent application of opposing interests to the Supreme Court of New York to compel the New York & Port Chester Railroad to change its line and among other things introduce a long curve. In opposing the change for the Port Chester Company the writer showed, by comparative run sheets and accompanying schedules, that the proposed curve would entail a loss of six seconds per trip. As the schedules provided for 200 trips each way per day, the total time loss per day equalled 2,400 seconds or about 40 minutes. As the estimated daily earnings were about $4,000 per day, the loss of 40 minutes of the use of the system per day was apparently a serious matter, and was so held by the court. In addition there entered the paramount consideration of public safety which was cited by the court as the most potent of the Port Chester Company's contentions in its replies to the proposed change of the line.

The reader should not understand from what has been said that it is desirable to always use short radii curves. On the contrary, the curve radii should be made as long as the conditions will permit. The controlling conditions are the angle between the tangents and the speeds which must be made on the curve to maintain the schedules. There are a number of tables giving safe speeds for different curves and corresponding super-elevations of the outer rail. Roughly, the speed in miles per hour which can be safely made on a curve is equal to the square root of the radius

of the curve, the radius being measured in feet. This will give an ample factor of safety and is only given as a rough general approximation.

Curves should be of the transition type and should preferably be at the stations or stopping places. When they are at the stations they affect the schedules the least.

If rivers are to be crossed by the proposed line this fact will usually affect the location. The banks of the river will have to be examined for suitable locations for the bridge foundations, and if the soil at all points is undesirable for this purpose the entire route may have to be altered so as to cross at a place favorable for bridging. If the course of a river is followed, the preliminary survey should include an examination of both banks to determine which is the more desirable, but if the river is easily bridged the route may cross from one side to the other occasionally, depending on the favorable nature of each side for road construction.

In connection with the subject of railroad location, it is pertinent to call attention to the inestimable advantages accruing from the keeping of accurate diaries. Not only should the engineer keep a diary wherein should be recorded at the end of each day, not only all occurrences, but some of his impressions and conclusions as well, but he should require the chief of the field party, together with the transitman and leveler, to do likewise. It is a good plan to call for these diaries at unexpected times.

Care should, however, always be taken to separate all facts from the engineer's conclusions in keeping diaries. While conclusions are sometimes valuable, the facts as they are or were are often imperative.

The practice of keeping such diaries, it might be mentioned, is often of equal value in other kinds of engineering work. In some important cases, upon the conclusion of the work the writer has had his entire diary relating to the construction typewritten, using a separate page for each day, and has presented one copy to his clients. From the

letters which have always subsequently been received acknowledging receipt of these books, it is evident that such records are appreciated.

When the field party has run the preliminary lines, the engineer has in his office, in connection with his personal investigations, all the data required for the following purposes:

1. Making an accurate paper location of the proposed route.

2. Making an estimate of the cost of the proposed railway upon which to base the financial scheme.

3. Making an estimate of the probable earnings of the proposed railroad.

4. Making an estimate of the fixed charges, such as the interest on the bonds, debentures, or other corporate obligations required, or money required to be borrowed or otherwise obtained to construct the road, and of the costs of operation and maintenance.

He is now ready to commence the Detail Investigations, etc., in order to carefully develop the details of the project, but before proceeding to do so, attention will be called to a few other very important matters.

If an engineer would be a success he must recognize as prerequisites of his intangible equipment:

First. The policy of Silence or Secrecy. Especially must he adopt this policy in his operations in and about cities and towns. His clients or the company employing him have a perfect right to a policy which is none of the concern of land boomers and real estate operators and speculators. Until the requisite real estate for the right of way has been acquired by the syndicate, secrecy is absolutely indispensable.

Second. The possession of Tact and Diplomacy. Both of these attributes are indispensable in order to retain the omnipotent public support and public confidence, and in dealing with legislative, executive, judicial, and other tri-

bunals, etc., such as common councils, town boards, various commissions, referees, arbitrators, etc., which the engineering and executive heads of railroads must do. He must never lose his temper no matter how great the real or fancied cause. Sound argument will generally prevail, and it should not be forgotten that ridicule is not argument.

Third. Uprightness. If he cannot, for any reason of policy or otherwise, tell the truth, it is better to make no statement whatever. He should cultivate habits of thought, listening, and silence, always remembering that a good listener is always welcome, and always carries away more information than a talker. At all events, he should not misrepresent or exaggerate. If he must and does talk, let him tell the plain, unadulterated facts, and do it in as few words as possible.

In carrying out the policy of Secrecy in and about the towns and population centers, it is often desirable to determine the preliminary field lines by the use of Stadia measurements. Such measurements require a very small number of men, who are generally mistaken for land measuring parties.

Above all, the preliminary reconnaissance and field work must be done in the most thorough and painstaking manner. The engineer need not be afraid that he may get too much data in regard to the distribution of the populations or their characteristics, or that he may obtain too many contours or too much other field information. The danger of too little information is far greater. It is very inconvenient as well as expensive to send a party back into the field for additional data which could usually have been obtained at the outset for a trifling additional cost.

One of the most effective resources at the disposal of the engineer for reducing the cost of construction and subsequent operation and maintenance is in the painstaking and detail consideration of the location of the line and the

exhaustive study of each and all of the elements which develop in connection with the determination of the location.

A good corps organized, as has been outlined, will make, on an average, about three-fourths mile per day for this class of work and do good work. Many parties make as much as three miles per day, but usually in relatively open country with the population closely congested only at certain distant points.

The cost of this preliminary field work, by which is meant the salaries and wages and board and lodging of the men and incidental expenses, will vary between $65 per mile of line as a minimum, where conditions are favorable, and $120 per mile of line, as a maximum.

The field engineering investigations and subsequent development of a proposed railroad enterprise may be divided as follows:

1. Reconnaissance.

Proposal of various alternate routes. Approximate cost of each, also approximate estimated earnings of each and relative costs of operation and maintenance of each.

2. Preliminary survey and investigations.

Selection of the most practicable locations for preparation of general maps. More reliable estimates of total cost and cost of operation and probable revenue. Paper location of lines, etc.

3. Detail investigations and office locations.

Preparation of maps and plotting data. Final office location of line, showing final alignment and elevations, also soil investigations, from which the approximate graduation cost is determined. Detail special estimates of probable revenue. Cost of construction and cost of operation.

4. Final field location, property maps, and office work.

(a) Cross-sectioning of the final line.

(b) Soundings or borings to accurately determine soil characteristics.

(c) Preparation of a complete detail continuous set and all individual property maps.

(d) General and detail plans and specifications.

(e) Letting of contracts for construction and placing in operation of the road.

There are cases where the engineer can pass directly from the reconnaissance to the detail investigations and surveys. In many cases the preliminary and detail investigations and surveys are not separated. It will usually be found far more satisfactory, certainly for the inexperienced engineer, to adhere to the subdivisions given above for the following reasons:

First. It will teach him the details of the process and accustom him to habits of accuracy and painstaking effort. There is at present entirely too much slipshod engineering, as well as engineering by proxy.

Second. When he once thoroughly knows the details of the processes he will then be qualified to determine himself what to do, or, probably better, what not to do.

Third. It is always better to do too much work rather than too little. A reputation for thoroughness, accuracy, and experience is the epitome of an engineering reputation.

Fourth. Thorough and experienced engineering is always ultimately profitable to both the capitalist and the engineer.

CHAPTER IV.

DETAILED OFFICE INVESTIGATION OF TRACK LOCATION.

The engineer is now prepared to arrive at conclusions from the data collected in his field survey. In doing this he should remember that the controlling features required for the success of high-speed interurban railways in the order of their importance are:

First. Safety to the public and the employees of the railroad in the operation of the road.

Second. Reliability of operation.

Third. Convenience and comfort of the public.

Fourth. An installation which, while fulfilling the preceding conditions, shall be so installed as to have a minimum cost for operation and maintenance.

The first condition will be most nearly approximated for high speeds, by locating, constructing, and operating the road on an individual or exclusive or a private right of way, by having no crossings at grade of any public streets, avenues, or highways or other railroads, and above all having no single track, with turn-outs or siding construction where cars pass each other. Single-track railroads have been and are the cause of the major portion of railroad casualties and receiverships. If the prospective business will not support the relatively small additional cost of another track, it is generally not worth going after. A large measure toward the fulfillment of the second condition will likewise be attained by the use of the private right of way, double track or individual tracks for cars going in the same direction, and the elimination of grade crossings throughout.

The convenience and comfort of the public will depend upon the location of the line and stations and also upon the equipment.

The fourth condition, and often the pivot about which the commercial success of the enterprise revolves, depends en-

tirely upon the character of the material used, the work done in the construction and equipment, and the design, arrangement, and disposition of the plant. There is no truer paradox than that "A cheaply installed railway is a most expensive one." It should never be forgotten or lost sight of in determining upon any elements of design or construction that railroads are built to be operated.

Fixed charges are absolute and determinable in advance for any given character of installation. The operating and maintenance costs of an installation poorly engineered and poorly installed are not only uncertain and indeterminable but unavoidably variable and cumulative.

The ideal commercial railroad line is not always, and in fact is hardly ever, the most direct route between the termini. The commercially ideal line is the one having a maximum of paying population per mile of road immediately tributary to its line. Centers of population are seldom in a straight line connecting the first and last of a number of such centers. The line must reach those places where the business will exist. It has repeatedly been proven that it is an error to suppose that centers of population will immediately extend or hasten to transfer themselves to accommodate a railroad. From this the writer does not wish to be understood as saying that increased transportation facilities will not develop the territory served. As a matter of fact, they certainly will, but the probability of competition which is generally supported by public opinion, where the convenience and comfort of the public are disregarded, should never be lost sight of. The best way to head off any possible dangerous competition is to secure the most advantageous and immediately remunerative location for the line and stations, having regard to fixed charges on account of real estate, etc. Consequently, from the preliminary data, routes should be selected which will pass well within the bounds of each of the population centers. Such routes should be carefully studied for the purpose of ascertaining the relative earning

and operating characteristics of these routes and the approximate costs of construction.

In some cases it is considered advisable to build the electric railway along the highway, and many of the present interurban roads have been constructed in this manner. This plan of course precludes high speeds, but it has the occasional advantage of locating the road where it is most convenient of access, and occasionally franchises can be secured for the use of a highway at a less first cost than if the right of way be purchased outright. Very frequently, however, this apparent advantage is more than obliterated by the annual "*compensation*" exacted by the authorities for the use of the street or highway. This "*compensation*" is nothing more than a fixed charge and should always be so considered. If this plan is followed the engineer must also be prepared to sacrifice an ideal alignment and grade line. Nevertheless grades and curves are not such serious obstacles to an electric road as to steam roads, and the resulting advantages of following the path of beaten travel, particularly the highway through a town or prosperous village community, are at times too great to be disregarded. An excellent plan in passing through such a town, where high speed is not a great desideratum, is to enter as far as possible over a private right of way parallel to and not too far from the main highway. If the railway is located, for instance, 300 to 400 feet from the highway it is sufficiently far from it to clear the houses and barns along the road and the entrances to them, and at the same time is sufficiently near to them to afford convenient transportation. The railway can then be turned into the highway when town limits are reached.

In determining upon a railroad installation it is entirely probable that at some point, which may be four or five miles or more from the main line as laid out, connecting the most important centers of population, there will be another center or centers of population, which it may be deemed desirable or preferable to tap. Such instances occur, not only where

there exists a relatively large fixed population of say anywhere between 5,000 and 10,000 people, but also in cases where noted recreation or summer resorts are already in existance. At first thought the tendency is to run a branch line to such points, from the main line.

Generally speaking, branch lines are not desirable. The reason for this is that trains running from the terminus of the branch line to a point on the main line are really nothing more than shuttle trains. The most desirable facilities cannot be given in such cases for the reason that, as a general rule, it is not profitable to run from either one, or both, of the main line termini through to the branch line terminus without change of cars. The result is that passengers are compelled to get out of the branch line car and transfer in order to reach their destination over the main line.

Again, the relative costs of operation per mile of branch line are, generally, considerably in excess of similar costs for main line operation. This is due, of course, to the fact that over such branch line there is a relatively small traffic. Notwithstanding this fact, trainmen, station agents, and other standard items of expense are maintained throughout the year, for the reason that the branch line must be kept in good condition as a part of the general system. In all cases where such relatively isolated centers of population or business points may occur, the proper way is to try and get the main line through such points, even if a slight detour is necessary, if the business in the near future bids fair to warrant this step. If such isolated business centers be, say five miles distant from the main line, the additional length of the main line due to running to such isolated points will, by no means, be increased by five miles. This statement will be apparent without demonstration.

In all cases where such circumstances may arise, the scientific method of procedure is to ascertain first what will be the additional cost of causing the main line to deviate from its course to such an extent as to take in the isolated center or

centers. Such additional cost, that is, the fixed charges plus the operating and maintenance costs of such additional mileage, should be balanced against the probable additional revenue which will result by deviating the line as indicated.

There are cases, of course, where branch lines can be shown to be preferable to running the main line out of its course. Such cases would occur, for instance, with large recreation resorts where the business would exist for but two or three months in the summer and where the company could cease to operate the branch during the winter or nonproductive period of each year. Under such circumstances, if the main line be deviated to include such points, we will have added for the remaining nine months of the year the cost of operating the entire car service over what will probably be an unproductive mileage. The determination of the advisability of deviating the main line or of constructing a branch line must be a matter of individual and separate estimate, determination, and judgment for each special case, and attention is called simply to some of the considerations entering into such problems.

In connection with this subject, another factor might be mentioned — that is, that a railroad company is liable at any time to be ordered by the authorities to run through cars from some branch line, should it build one, to one or both of its termini. Such a condition might very seriously affect its operating arrangement, and consequently the costs of operation.

It must not be supposed that railroad companies can run railroads entirely as they please at the present day. The Railroad Commissions in most of the States are being vested with greater and greater powers. Such powers include among others the right to fix the schedules and even the routing of cars. These rights, of course, are given the Railroad Commissions for the purpose of facilitating public convenience and protecting the interests of the public. At the present time the public is an omnipotent entity which is making itself

felt. Unfortunately, at times, public demands are not entirely just, and some of these demands undoubtedly work unnecessary hardships upon railroad corporations. In order to avoid what may be a very material hardship in the event of the necessity of changing the routing of cars and conse-

VIEW ON THE WYOMING & LACKAWANNA VALLEY RAILWAY, A THIRD RAIL ELECTRIC ROAD.

quently the schedules of the entire system due to the existence of one or two branch lines, this fact must be considered. In other words, the advisability of constructing branch lines or of deviating the main line so as to take in the isolated centers or of paying no attention to such cases should be gone

into fully with this contingency in mind and determined in the original design.

Considering the actual work of laying out the line, each of the preliminary routes surveyed as described in Chapter III is now taken up in detail in the office of the engineer. Each is plotted and those individual characteristics relating to alignment and grades studied for the purpose of ascertaining whether any of the routes presents any relatively serious or prohibitive construction or operative characteristics.

In connection with this part of the work it will not be out of place to say a few words with reference to the scales used in plotting the preliminary lines. A small scale should not be used on account of the difficulty which will be experienced in satisfactorily plotting the houses, barns, and other buildings along the line of route. It is always advisable to plot these buildings and their immediate surroundings to scale, and where many such buildings occur at any locality to use a horizontal scale of 150 feet or 200 feet to the inch. In more open country a scale of not over 400 feet per inch is used. The vertical scale (for the profile) is generally taken at 20 feet per inch.

In the preliminary field surveys as described in Chapter III, the character of the soil and rocks was carefully noted, especial attention having been paid to the matter of stability for the purpose of determining the required rate of the side slopes of the cuts and embankments.

In fixing the grade lines a study should also always be made of the virtual or momentum profiles of each tentative set of grade lines. A virtual profile is that obtained by plotting vertically to scale, at each point along the road, the height in feet to which the momentum of the train at such point would raise it vertically. When those points are connected by a line we have the virtual or operating profile. Such a computation of course involves the question of speed. For existing steam roads, as well as their successors — the

heavy and high-speed electric passenger or freight roads, momentum profiles are of the utmost importance from the point of view of operating costs, as such costs are affected by the permissible length of trains and energy consumption.

Momentum profiles are also important factors in determining upon grade lines, and consequently the relative amount of cut and fill. As they determine conditions and costs of operation it is a matter of comparing an operating cost with a fixed charge as represented by the interest on the cost of a given cut or fill.

The grade lines in cross-country work are determined in the usual manner by stretching a piece of thread between points. In doing this the engineer should note that the line of the thread is at the proper distance above or below the existing grades of all public highways or other railroads crossed by the line of the road, if no grade crossings are to be used, or at the proper level if the grade crossing has been adopted.

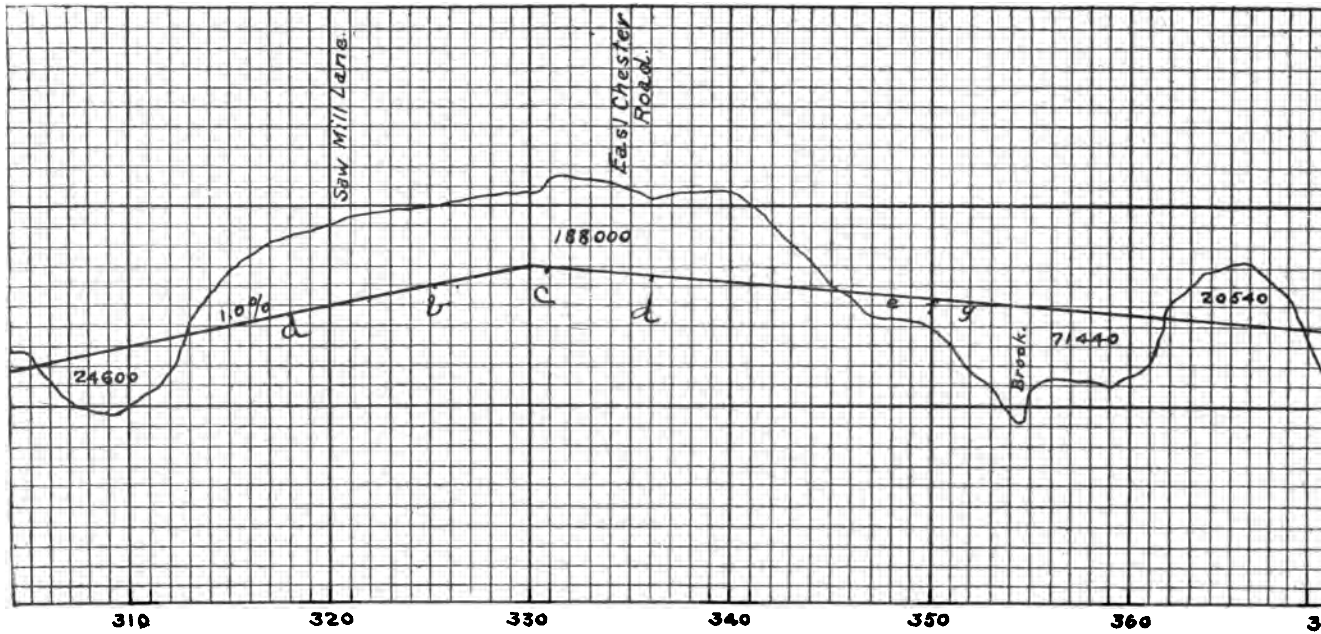
For all public highways, where the highway passes beneath the subgrade of the proposed road, it is usual to set the line of the thread 18 feet above the grade of the highway where the proposed railroad passes over the highway. With the tentative grade lines now penciled in, an approximate estimate is made of the probable cut and fill.

It is especially desired here to call attention to the necessity, in the design of high-speed interurban and other rapid transit systems of this class, for the provision of subways or under-crossings, where the grade of the tracks is beneath the grade of the street or highway, or tunnels of ample height and width. All such subways or tunnels should be capable of permitting the standard steam railroad cars to readily pass through them on account of probable future developments and traffic arrangements with steam roads. A system designed with reference to steam road conditions will undoubtedly have a far greater present and especially future value than where such conditions are neglected or ignored.

The cut on p. 34 represents part of a profile of a road and shows the elevations of various points as well as the grade line. Here the slopes were taken as $1\frac{1}{2}$ to 1, that is, for each vertical height of 1 foot the horizontal distance will be $1\frac{1}{2}$ feet. For two-track construction, the width of the subgrade should not be less than 26 feet. To determine approximately the volume of earth to be removed, proceed as follows:

Measure the distance between the grade line and the line of the profile for a number of points, as at a, b, c, d, etc., in the profile, locating the successive points so that the slope of the ground between any two adjacent points will be approximately uniform, or so that the surface of the ground between adjacent points will be approximately in the same plane and, if possible, approximately parallel to the proposed grade line. At each point so located if we pass a plane at right angles to the grade line, and assuming the side slopes as already given ($1\frac{1}{2}$ to 1), and the subgrade as 26 feet wide (for a double-track road), and further assuming that the surface of the ground is approximately level and parallel to the subbase, we have cut out by the plane above referred to a polygon with two of its sides approximately parallel. Computing the volume of the solid between two of the adjacent polygons gives us the approximate quantity of excavation of embankment, as the grade line is below or above the surface of the ground, for each pair of planes. Where the ground is very uneven those sections or planes must be taken very close together. In cases where the plane of the profile deviates considerably from that of the grade line, the prismoidal formula must be used in determining the volumes of cut and fill.

For the approximate conditions which we are now discussing, the polygon referred to in the foregoing paragraph is usually taken as a trapezoid, of which one of the parallel sides is the proposed subbase of the road. Such approximate computations are generally based upon sections or planes taken 50 or 100 feet apart. For these approximations, where



TYPICAL PROFILE OF AN ELECTRIC LINE.

the section is that of a trapezoid, just referred to, a table or set of tables known as earthwork tables must usually be prepared for different side slopes and widths of bases, showing the total quantity of earth cut or fill per 50 feet or 100 feet of length or distance between parallel planes for each one foot or any given decimal part thereof, of increase in the height or length of the line adjoining the two parallel sides of the trapezoid and perpendicular thereto. Such tables are also to be found in any of the numerous civil engineering handbooks, and at times, occasionally, in works on civil engineering. If it be found that the data used in compiling any of the tables of the handbook, are the same as that for any special case under consideration, there will, of course, be no need for compiling a table. I have not often found such printed tables applicable.

Each of these quantities is written on the profile and at the same time indicated, as rock or earth cut, etc., from the data taken by the preliminary field parties. At some convenient place on the profile are grouped, under the heads of Earth Cut, Rock Cut, and Embankment, the respective quantities of each class of work. It should be noted that in fixing grade lines, it is often very essential not only that the cuts and fills be approximately equal, especially in work in and around towns and cities where earth for filling purposes has a value, but that the cuts and fills should be so located as to enable the product of the cuts to be used for embankments without too much unnecessary expense in transportation.

Earthwork contracts generally provide that the earth or other material taken from excavation shall be hauled or transported a given distance (from 1,000 to 3,000 feet) without extra charge. Earth and rockwork contracts are generally let on the basis of the cubic yard.

The foregoing method of computation is of course an approximation. The results will always be on the safe side if reasonable care be used and the distance between parallel planes be properly taken. This will certainly be done if the

estimates be made by and under the direction of the chief of the preliminary surveying parties or the transitman or leveler of the field corps, each of whom has impressed upon his mind the characteristics of the surface of the country through which the line has been located.

The ultimate or final earthwork determinations are matters of much importance and detail and require careful and experienced work and computations.

The profile should be divided into sections, of two miles or more in length, and the data relating to quantities, costs, etc., for each section shown on the section.

The cost of grade crossings and culverts is now taken up for each section from the number of such crossings and culverts taken on the preliminary surveys, and the more detailed cost of the enterprise to subgrade then determined. The determination of the costs of the rails, etc., ties, and ballast is only a matter of simple multiplication and addition.

Careful attention should also be paid to all vertical curves, by which are meant the curves connecting the consecutive grade lines. In the case of train operation this is an important detail, especially where two descending grades meet, for the reason that at the lowest point the rear cars may be pushing or crowding upon the cars which have passed the lowest point, and thereby, in cases of too sudden changes of direction, cause disastrous results.

For vertical curves, the elevations may be determined by taking the sum of the intersection gradients and dividing by two for the ordinate of correction of the grade line or grade curve from the point of intersection or apex of the two grade lines, and then taking one-fourth of this quotient as the ordinate of correction for the next station, in both directions from the intersection, and so on. Thus, with two grade lines, of which one was 1.25 per cent. and the other 1.00 net, we should have

$\frac{1.25 - 1.00}{2} = 1.12 =$ ordinate at the apex of the vertical curve from the point of intersection of the grade lines;

$\frac{1.12}{4} = .28 =$ ordinate of correction for first station (100 feet distance) on each side of the intersection of grade lines;

$\frac{.28}{4} = .07 =$ ordinate of correction for the next two stations of 100 feet each from intersection of grade lines. This process can be followed until the vertical curves merge into the grade lines.

CHAPTER V.

PRELIMINARY DETERMINATION OF SCHEDULES AND EQUIPMENT.

We now come to the determination of the equipment, such as number of cars, size and disposition of power stations, feeder conductors, etc. The determination of the rolling stock, or cars, is the first step, and what is wanted is the maximum number of cars required to properly do the estimated maximum business. The number of people to be moved in one direction in one hour generally determines the capacity of the road.

On his preliminary investigation or reconnaissance, the engineer has noted the occupations, character, and habits of the people of the different population centers. He has also noted the existing community of interest between the respective cities, towns, villages, etc., as well as the relations and approximate travel between each of the centers of populations and the terminus or termini. He has ascertained the time intervals as well as the amount of heaviest traffic. The rolling stock is usually determined by the business accruing during a few hours of the morning and a few hours of the evening.

Let

$P =$ number of people required to be carried.

$Q =$ time in hours during which business of P lasts.

$M =$ number of people one car will hold.

$S =$ schedule speed in miles per hour (including 15 or more seconds for each stop).

$H =$ headway in minutes.

$D =$ length of line in miles.

$N =$ number of cars, if single cars be used, or train units, if more than one car be used.

$T =$ time in minutes occupied in running between the termini during one single trip.

Then

$\frac{P}{Q}$ = number of people to be carried per hour.

$\frac{P}{QM}$ = number of cars required, which if single cars be used $= N$.

$\frac{D \times 60}{T}$ = schedule speed in miles per hour $= S$.

The formula connecting N, S, D and H is

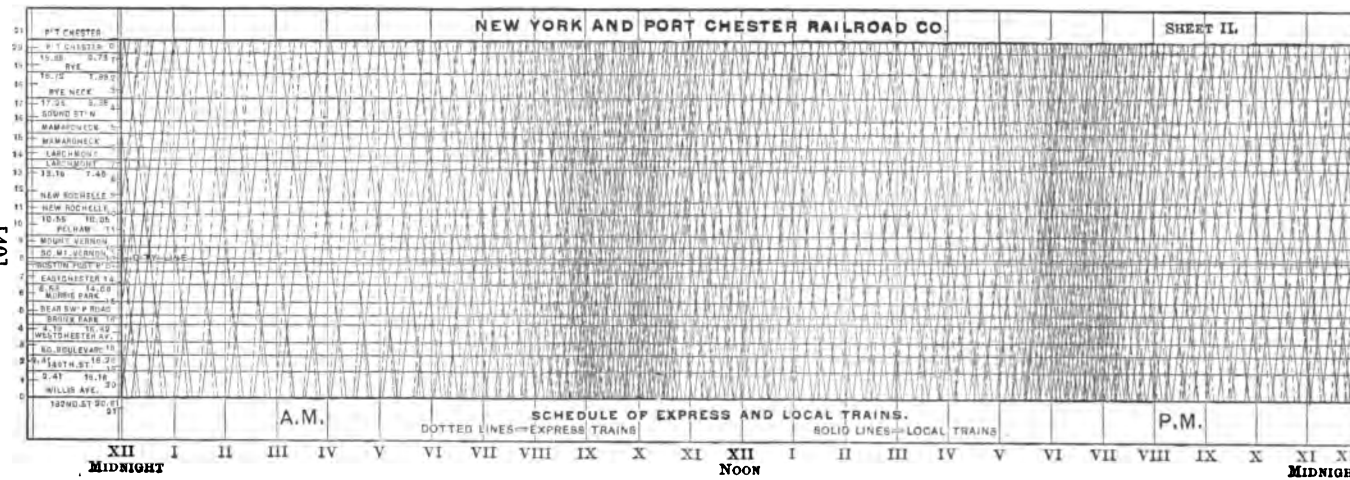
$$N = \frac{120 \times D}{S \times H}$$

which by transposition is

$$H = \frac{120 \times D}{S \times N} \text{ or } S = \frac{120 \times D}{H \times N}$$

The foregoing, together with the knowledge of the probable amount of the heaviest business, will give at once the number of cars or train units by assuming the schedule speed, and headway, or if the number of train units be fixed in advance, by assuming the schedule speed, the required headway is at once shown.

We now have the number of cars or train units which is required to do the estimated maximum business, together with the minimum headway. The next step is to determine the time-table. This is necessary in order to arrive at a conclusion as to the capacity of the power-house, substations, and transmission system. The best way to do this is to do it graphically, as shown in the diagram on the next page, which was prepared to show the schedule of the New York & Port Chester Railroad. The original sheet, of which this diagram is a reproduction, is 60 inches long and 30 inches wide. The sheet is simply a properly selected co-ordinate paper, mounted on cloth to protect it by preventing it from being torn, ruled horizontally and vertically. The paper used for this work was millimetre paper. The vertical lines are one millimetre approximately 1/25 of an inch apart, and every sixtieth vertical line is a heavy line. The fine lines of the horizontal



SCHEDULE OF EXPRESS AND LOCAL TRAINS.

axis represent minutes and the heavy lines the hours. The vertical axis is a representation of the stations of the combined express and local schedules. Each station or stop is represented on the vertical scale at its proper distance, to scale, from the termini which are the first and last stations shown on the vertical scale.

Commencing now at midnight and at the southern terminus, a straight line is drawn from the zero or midnight at such an angle with the axis of abscissæ as to intersect the line drawn through the northern terminus (Port Chester) 31 of the small divisions farther to the right (for the express service), as the express schedule is 31 minutes. Each of the other express runs, in the same direction, is represented by a line parallel to the first line, but each started at its proper time on the axis of abscissæ. The express runs from the northern terminus are likewise represented by lines drawn from the northern terminus and sloping to the right. The same process is pursued for the local runs, noting, however, that the time is 49 minutes for the local trains. The express runs are represented by red lines and the local runs by blue lines for convenience in distinguishing them.

The express stations on the axis of ordinates are shown in red and the local in blue. These red and blue lines are drawn through the stations, parallel to the time axis or abscissæ, to readily show the time at which any train leaving either terminus, on any of the runs indicated by the sloping lines I have just explained, will pass the stations, which time is shown by the intersection of the line through the station with the run lines. To make this chart absolutely correct, the local and express run lines should each show at each station a small break, equal to the allowed time interval of each stop, that is, 15 seconds. This detail is shown in the final charts. In addition to this chart, showing the combined local and express runs, separate charts are prepared showing separately the local and express services for convenience. The chart of the total ser-

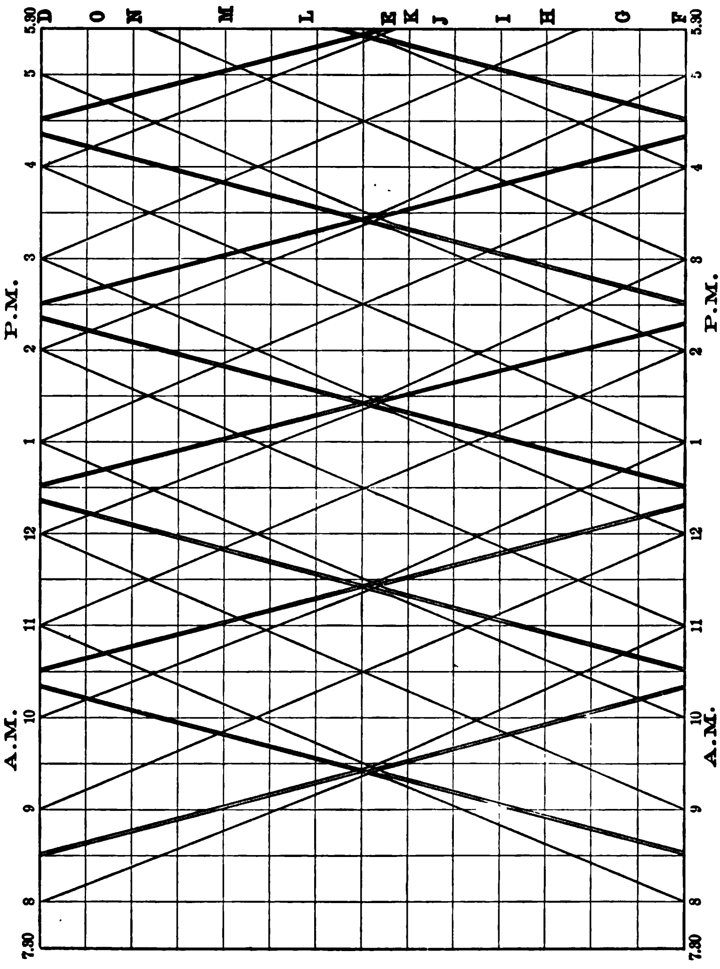
vice is necessary to determine the total load curve of the main power station, which will be taken up later.

If the road is a single-track line this form of time-table will immediately show the proper location of the turnouts. For instance, the cut on p. 43 shows a time-table for a single-track railway. The express runs are shown by the double lines and are two hours apart. The local runs are indicated by the single lines, and turnouts must be provided at the points where these lines cross. As a matter of fact, the time-table, which was prepared by Mr. Ernest Gonzenbach for a single-track electric railway, really shows three classes of possible service, viz.: (1) The express service, which takes 1 hour and 50 minutes to run the 62 miles between D and F; (2) A mixed local and express service which can make the run in 2 hours and 25 minutes, and (3) a local service stopping at all stations and requiring 3 hours for the run. Class (2) can be made up by running 2 or more cars on the express (or double) line to the point E and running 1 or more of them as an accommodation car or train from that point.

Another instance of the use of such graphical time-table is shown on p. 45. It will be noted that this cut shows some of the details of the electrical distribution systems. The instances given of this method of representing time-tables as shown on p. 40, together with the two foregoing illustrations are sufficient to indicate the value of this means of determining the details of time-tables, distributions systems, etc.

The cut on p. 44 illustrates an extension of the foregoing method. This diagram shows a comparison of trains running, the comparison being made between the train services of the New York & Port Chester Railroad, express and local and total train services, with the train service of its competitor, the New York, New Haven & Hartford Railroad Company.

At this stage we are chiefly concerned to learn the *maximum* load which will be on the main power station. We can either determine this quite accurately by determin-



TRAIN SCHEDULE FOR A SINGLE TRACK RAILWAY.

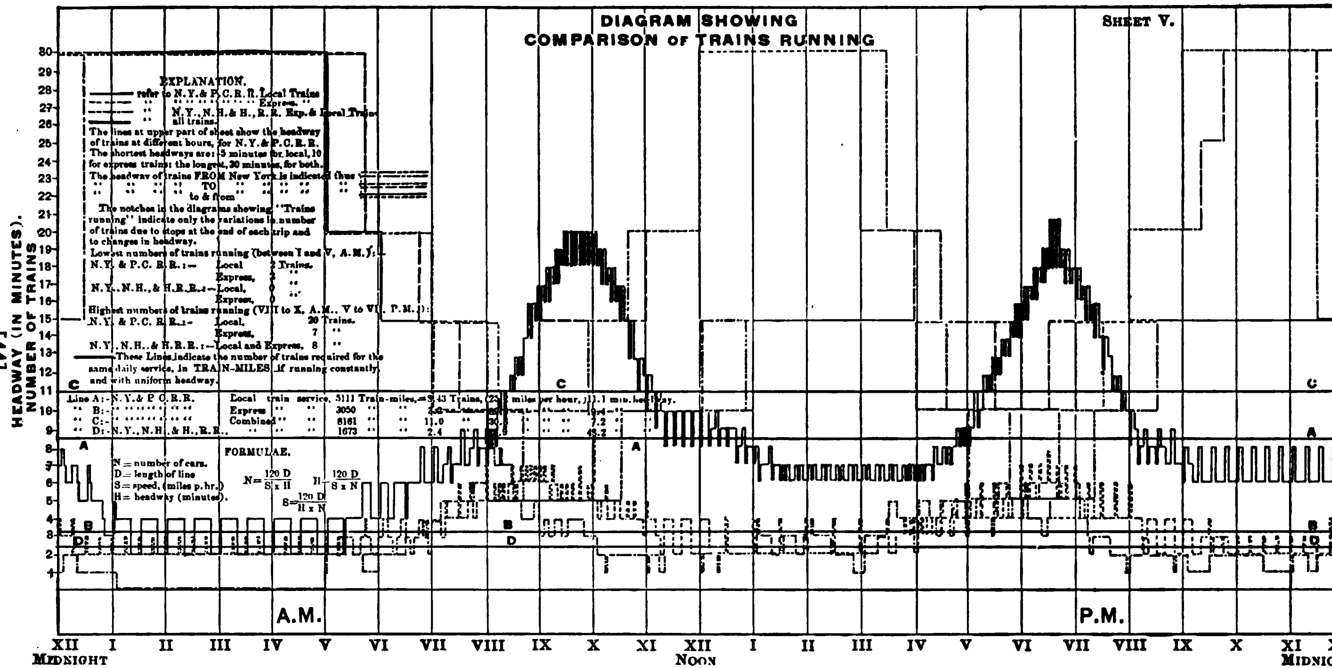
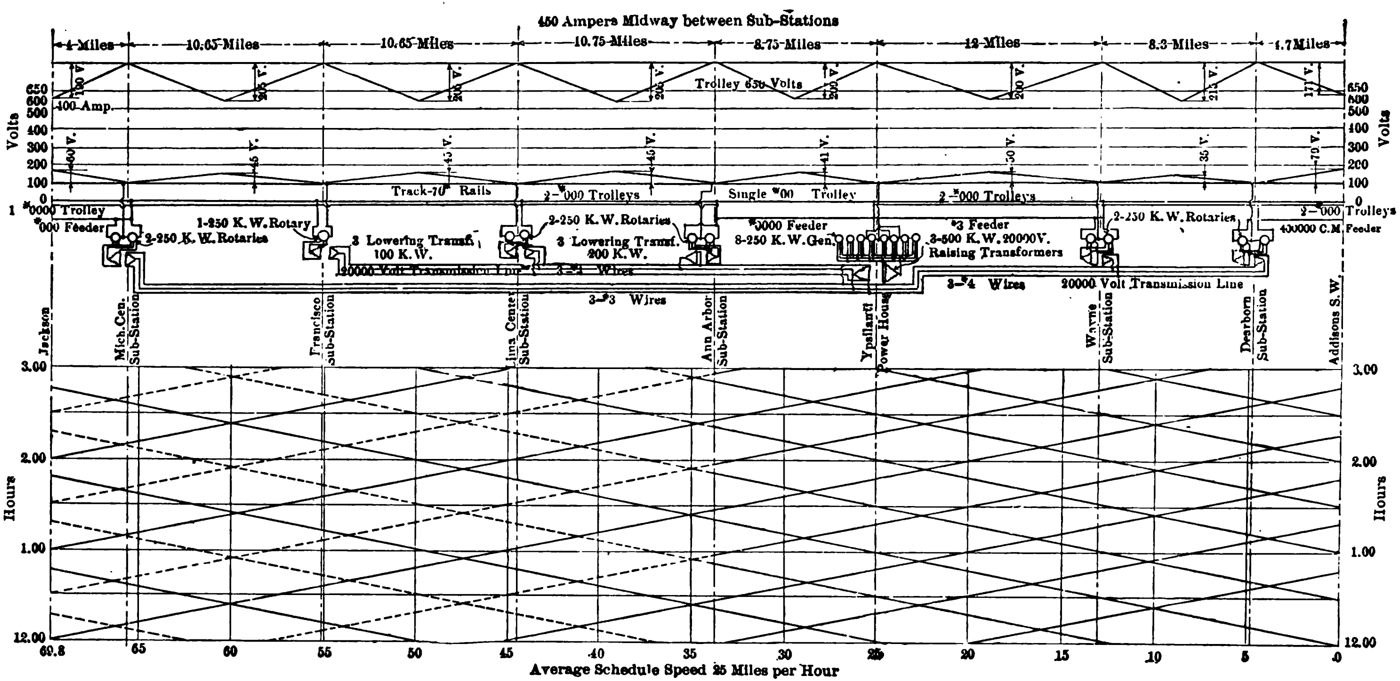


DIAGRAM SHOWING COMPARISON OF HEADWAYS AND OF TRAINS RUNNING BETWEEN NEW YORK AND PORT CHESTER.



TRAIN SHEET AND DIAGRAM OF ELECTRICAL DISTRIBUTION — DETROIT, YPSILANTI, ANN ARBOR & JACKSON RAILWAY.

ing each individual load curve from such data or run curves as are shown in Plates I, II, etc. From such individual run sheets a total run sheet, that is a run sheet showing continuously instantaneous values and variations of energy for the entire run between termini, can and in all exact work should be prepared. From such a total run sheet the maximum energy or current consumption can readily be obtained by superimposing or graphically adding the energy or current curves at the time or times of maximum service.

The preparation and study of such individual run sheets will be taken up in detail in Chapter XIII, on rolling stock and motors, but is referred to at this point because a preliminary approximation of the maximum current requirement is necessary at this stage of the investigation. On each of the cuts the horizontal axis represents time, while the vertical axis represents speed in miles per hour and energy consumption expressed in kilowatts per car. At a convenient place, on each of these diagrams, it is usual to tabulate the data for the different runs. The separate tentative runs are indicated by the lines A, B, and C; A and B being high-speed runs, and C a slow-speed run.

The areas inclosed by the energy-time curves are shown shaded, and where they are superimposed, the fact is indicated by a finer shading, as well as by grouping the characteristic letters, or A, B, C. Thus, the first part of each diagram, showing the part of the car and its acceleration from full stop to the particular maximum speed attained during the first acceleration, being common to all the curves, has the energy area finely shaded, and also marked with the letters A, B, C, corresponding to all the curves. When points are reached at which the acceleration for any of the three curves, A, B, C, is discontinued, which point is also the point at which the current is cut off from the electric motor, the fact is readily indicated by the difference in the shading, and the lettering of the shaded portion.

In all the charts, the data given at the lower portion of the chart, in relation to curvature, grades, and fractional distances of the run, are those which correspond to the local train curve, C, in every case.

We will now compare the results of these runs. Taking that on Plate I, for example, as shown, the time consumed for run A is 2 minutes and 5 seconds; the time consumed for run B is 2 minutes 6 seconds, and the time consumed for run C is 2 minutes 18 seconds. It will also be noticed that for run A the energy consumption expressed in watt hours per ton mile is 144.2, while for run B it is 122, and for run C it is 89.4. In other words, for a difference in time of only 13 seconds, as compared between run A and run C, over a distance of 1.448 miles, the difference in energy consumption per ton mile is 54.8 watt hours per ton mile. Assuming the line 25 miles long, which would give 50 miles for a round trip, and assuming the weight of a loaded car for this service as 50 tons, the ton miles per round trip would be 2,500; multiplying 2,500 by 54.8, which is the increased watt hours per ton mile for a schedule 13 seconds faster, we would have an increase of 137,000 watt hours per round trip, or 137 kilowatts. A kilowatt hour at the main station switchboard would cost about 6 mills. At the track it would cost about 1 cent, assuming the very best conditions. At this rate the increased cost per round trip on the road we have been assuming would be $1.37. Assuming 150 round trips per day, which would be the approximate service on a high-class road in relatively densely populated territory, we would have an increased cost of $215.50 per day due to the faster schedule, which for the total length of the line would not make a difference of 5 minutes in the running time per trip.

This actual increase in the cost of energy due to the slight decrease in running time is not the only increased cost which would accrue. There would be in addition an

increase in cost due to the necessity for larger conductors for the electrical transmission systems, as well as the probably additional increased cost due to the necessity for the installation of additional storage battery capacity in the substation to take what would be an increased peak load in the case of the faster schedule.

Attention is called to a few of these considerations, in order to show the value of a careful determination and most careful study of speed time curves and run sheets for each individual case, and the determination of the schedules therefrom. The engineer should guard against a mistake which has not infrequently been made, and which is that of specifying in advance, without making this detail study, that a schedule speed, including station stops, of a given number of miles per hour shall be made. A cautious engineer will never do this. Perhaps one reason why it has been done heretofore is the supposition that almost anything could be obtained from an electrically propelled railroad system. This may be relatively true if the omnipotent commercial considerations are not allowed to enter.

With the advent of heavy and high-speed electric traction it has been found necessary to make a great number of such individual run sheets for different cases for the purpose of determining the energy consumption in watt hours per ton mile for different schedules and conditions. The reason for this was that there were no reliable data in existence upon which any estimate could be based. A great number of these run sheets have now been completed for different cases, and where they have been carefully done it has been found that the actual operating results coincide, within a very few per cent., with the theoretical considerations deduced from the run sheets.

The determination of the load diagram, by the use of total run sheets as just outlined, is a long and laborious task, and cannot be taken up in detail in this book. The follow-

ing, however, is a method of approximation which can be followed:

Let

W = maximum weight of loaded car, or train unit, in tons, of 2,000 pounds each.

D = length of road.

T = time in minutes occupied in running between termini = one single trip.

K = energy consumption in watt hours per ton mile.

N = number of cars or train units on the road during time of maximum service of minimum headway.

Then we have

$W \times D =$ ton mile per trip $= P$.

$\frac{P \times K}{1000} =$ energy per trip in kilowatt hours.

$\frac{P \times K}{1000} \times \frac{60}{T} =$ mean rate of energy input per car or train unit.

$\frac{P \times K}{1000} \times \frac{60}{T} \times N = A =$ total maximum average energy required at the car motors for maximum service condition.

If to the foregoing 25 per cent. be added for transmission losses and heat and light, we have:

$\frac{60 \times P \times K \times N \times 100}{1000 \times T \times .75} = 0.08 \frac{P \times K \times N}{T}$ maximum average demand $= R$.

To R must be added the fluctuations, which will vary from .2R to .33R, as the number of train units in regular service are great and the average load consequently relatively high, or as the number of train units in regular service are few and far apart, and the consequent relative increase of the load during certain hours relatively great.

In the foregoing, the quantity K is the important, in fact the crucial, quantity. K will vary with the schedule and the location of and the distance between and consequently the

number of stops or stations, as well as with the alignment and gradients. As this is of such importance, I have compiled in the accompanying Table III, data showing relations between schedule speed and energy consumption in watt hours per ton mile. These figures are based upon approximately straight and level roads. As the effects of grades upon energy consumption are, to a large extent, compensating, the data may be used with safety. The compensating effect above referred to is due to the fact that while a car going up-grade is consuming more energy, per contra a car going down-grade consumes much less or none, thereby equalizing the effect of or compensating for the gradients.

We now have determined the maximum load to be provided for, and from this figure we determine the number and size of the main generating station prime movers, such as the turbines or reciprocating engines, and the accompanying direct-connected electric generators.

Generally speaking, the fewer the machines the better, always bearing in mind the necessity for the provision for such a number of units as will assure uninterrupted operation in the event of the disability of any single unit.

TABLE III.

Distance Between Stops.		Watt Hours per Ton Mile for Schedule Speeds of					
Miles.	Feet.	40 Miles per Hr.	35 Miles per Hr.	30 Miles per Hr.	25 Miles per Hr.	20 Miles per Hr.	15 Miles per Hr.
3	15,840	110	80	78	65	53	40
2½	13,200	121	90	83	74	54	40
2	10,560	142	99	86	80	60	41
1½	7,920	....	123	95	85	68	43
1	5,280	....	....	123	90	74	50
½	2,640	....	....	....	145	119	56
¼	1,320	....	....	....	....	....	120
Train friction in pounds per ton..................		35	30	27.5	25	20	15

The braking effort or retardation is taken at 150 pounds per ton. The stops are taken at 15 seconds each, except in the case of the 15-mile per hour schedule, where 10 seconds is taken.

The foregoing figures are for cases of approximately level and approximately straight roads.

For a schedule of 40 miles per hour the speed attained will be between 60 and 65 miles per hour. A schedule of 25 miles will require speeds of from 40 to 50 miles per hour, etc.

The rate of acceleration for the long runs varies from 75 to 110 pounds per ton, going as high as 210 pounds per ton for short runs.

The foregoing applies to single car units. If units of more than one car be used, the friction in pounds per ton will decrease and with it will also decrease the energy consumption in watt hours per ton mile.

Some of the places have been left blank on account of the impracticability, with existing apparatus, of making some of the high schedules with the short distances between stops assumed in the table.

The figures are for the energy required at the motors.

Cost of Construction.

The engineer is now prepared to make up at least tentatively his estimates of cost. To give definite figures which will apply in every case is of course impossible, as prices for nearly everything which enters into railway construction vary not only with the market but also with the territory in which the road is to be built. For instance, ties can be purchased in the South and in many parts of the West for 40 per cent. of the New York price; the cost of ballasting depends largely and of bridging entirely on local conditions. Nevertheless the writer has compiled Table IV as giving safe average figures for a double-track, high-speed interurban line, such as called for by modern practice.

TABLE IV.

Approximate Costs per Mile of Single Track.

ITEMS.	Maximum.	Minimum.
Rails, 80 lb. T. ($33 per ton delivered, including splice plates, bolts, spikes, and drilling	$5,100 00	$4,460 00
Cost of labor for handling and laying	900 00	900 00
Track bonding..................................	750 00	400 00
Ties, 6x8x8, white oak, at 70 cents each	1,848 00 (2-foot-centers.)	1,474 00 (30-in. centers.)
Rock ballast, 10 inches deep, 11 feet wide, and carried to top of tie	4,125 00 (Crushed stone, $1.50 per yard.)	2,062 50 (Crushed stone, 75 cts. per yard.)
Graduation	6,000 00 (20,000 cubic yds. per mi. of track.)	1,800 00 (10,000 cubic yds. per mi. of track.)

TABLE IV — Continued.

ITEMS.	Maximum.	Minimum.
Third rail	$7,000 00	$3,400 00
Copper or other electrical conductors, and installation thereof	2,500 00	1,500 00
Bridges and culverts	12,000 00	4,000 00
Labor and incidentals	400 00	200 00
EQUIPMENT.		
Rolling stock, motors and equipment, from $10,000 to $5,000 per car	8,000 00 (At five minute headway.)	1,000 00 (At one hour headway.)
Power-stations at $100 per kw.; substations at $40 per kw., etc	18,000 00	4,000 00
Incidentals, including block-signal system, telephone and telegraph, fencing, etc	4,000 00	1,000 00
Real estate for right of way	20,000 00	1,600 00
	$90,623 00	$27,796 50

In the foregoing table are shown the approximate maximum and minimum costs per mile of road. The maximum costs above given will prevail in and around large cities, such as New York, Boston, London, and Paris, where such items as cartage, storage, labor, etc., are relatively high. Terminals are not included.

The cost of bridges and culverts is probably the most indeterminate item in the above list. As already indicated, it is assumed that the road is built upon a private right of way, and that grade-crossings are eliminated.

The estimates for construction are based upon material and workmanship, upon which the subsequent maintenance will be a minimum.

The estimates of Table IV for the bridges and culverts are all based upon concrete-steel structures. These structures, when once erected, require practically no further attention, as they are simply monoliths. Their cost is no greater than that of the best class of steel construction. The average cost of one of these structures for four tracks, having a clear width or span of about 60 feet, and a clear height from the top of the street to the center of the under-

side of the structure, of about 16 feet, is about $9,000 where no piling is necessary and where a foundation can be obtained by excavating to a depth of not more than 5 or 6 feet. A two-track structure is worth about 35 per cent. less.

If the item of bridges and culverts be eliminated from the total, and the sum of the figures set opposite the remaining items be taken as the totals, the maximum and minimum for any given special case can very readily be determined, by roughly estimating the number of grade-crossings per mile, and adding it to the above total.

TYPICAL WAITING STATION — LACKAWANNA & WYOMING VALLEY RAILWAY.

The maxima of the foregoing estimates are based upon the highest-class construction, and an operation providing for headway of 5 and 10 minutes between the train units during the morning and evening commercial hours on roads having not over 100 miles of single track. The headway throughout the day is about 20 minutes for the maximum estimates.

The minimum estimates will allow headways of half an

hour or more throughout the larger portion of the day, with headways of probably 10 and 15 minutes during the morning and evening hours.

The character and amount of the equipment will be determined entirely by the size, character, business and habits of the population tributary to the line of the road. This matter will be taken up later.

The cost of real estate for right of way and terminals, and other purposes, will vary from $100 per acre to $8,000 or $9,000 per acre, or more. This item will also have to be determined separately for each case, and it is simply given in the foregoing table to show the difference between the maximum and minimum costs as such costs now exist.

The following is an actual table of costs of an interurban railway, taken from an article by Mr. Ernest Gonzenbach in the *Street Railway Journal* of April 4, 1903. The road from end to end is 62.5 miles long, but counting the mileage of sidings and yard-tracks it has a single-track mileage of 66 miles.

TABLE V.

Cost of Interurban Electric Railway 62.5 Miles Long.

Excavation and embankment	$96,000
Bridges, abutments, and culverts	91,050
Two overhead railroad crossings, at $32,000	64,000
Ties, 2,640 per mile, at 55 cts	96,250
Ballast, 2,200 cubic yds. per mile, at 80 cts	116,000
Rail, 70 pounds per yard, at $31 per ton delivered	225,000
Joints, spikes, and bolts for 60-feet rails	29,500
Labor on track, 56 miles, at $600 per mile	33,600
Labor on street track, 6.5 miles at $1,800 per mile	11,700
Farm and highway crossings	9,500
Wire fences, 24,000 rods, at 73 cts. in place	17,500
Switches, special work, etc	21,000
Bonds, 24,000, at 61 cts. in place	14,650
Cross-bonds and special bonding at switches, etc	2,000
Third-rail, 70 pounds per yard, 56 miles, at $36 per ton delivered	131,000
Insulators, spikes, and bolts, at 62 cts. in place	18,000

Joint-plates, bolts, and labor laying rail	$9,800
Bonds, 15,000, at 73 cts. in place	10,950
Crossings and crossing-cables	13,500
Trolley in streets, single-track span construction	24,000
Power station, 1500 kw. at $120 per kilowatt	180,000
Power station building, $11 per kilowatt	16,500
Transmission line, 55 miles, at $1,400	77,000
Substation freight and depot buildings	24,500
Substation railway apparatus	65,000
Batteries	80,000
Telephone line	9,000
Block-signal system	35,000
Stations and platforms	5,250
Switch and platform-lighting circuit	4,000
General office building	8,000
Car shops, shop tools, etc.	24,000
Car bodies and locomotive body	49,000
Trucks and air-brakes	27,500
Electrical car equipment	76,000
Lighting and power apparatus and supply systems	70,000
Accidents, contingencies, and insurance 5 per cent	89,000
Administration, superintendence, office expenses, engineering, etc., 5 per cent	89,000
	$1,963,750

The figures above do not include any allowance for right of way, franchises, and legal expenses, nor for interest during construction. It represents the construction cost purely, which in this case amounts to $29,750 per mile of single track.

CHAPTER VI.

ESTIMATE OF EARNINGS.

We will now make a detailed estimate and statement of the probable income or revenue of our proposed road. This detail should show:

1. Estimate and money value of probable passenger business between each of the centers of population and the principal terminus or termini, if both be important places.

2. Estimate and money value of probable passenger business between each of the centers of population between the termini and each of the remainder of such centers of population.

3. Estimate and money value of the probable annual excursion or recreation passenger business.

4. Estimate and money value of the probable express and freight business.

5. Rates of fare which are proposed to be charged. Should an existing road or roads be occupying the territory proposed to be served, the relation between existing rates of fare and the proposed rates is of course an important factor in this latter consideration.

As a matter of fact, instances of totally unoccupied territory are very rare. Trolley roads are almost certain to be in operation and generally, in instances of most promise, steam roads will be found serving the territory after a fashion.

A knowledge of the business of the existing railroads operating in the proposed territory is generally of value and should be ascertained.

For steam roads this can be readily done by purchasing one ticket, at each station within the territory to be served, to every other station on a certain day of the month, and then repeating the purchases at given intervals, say ten days

apart for some months. As each ticket has a serial number the existing local and through passenger business for any territory can be readily determined by noting the serial numbers and subtracting the numbers on those first purchased from those last purchased. This method will also show the variations of the passenger traffic.

The business of the surface trolley roads can be determined by stationing men at predetermined important places along the routes and noting the car number, time of day and number of passengers on each car as it passes a given point. For this work some experience is necessary to estimate the number of passengers on the car as it passes the observer. It is remarkable how accurate a little experience and care will make such observations. The difference in the number of passengers on a car as shown by the observations of the consecutive observers will show, approximately, the amount of local business or business between centers of population. These observations will also show, approximately, the total trolley passenger business for the territory and will provide data from and for the actual case in hand, from which can be determined the rides per capita for the territory as a whole as well as the rides per capita between the different centers of population. It is needless to say that the detailed data above noted will not be supplied by the existing operating railroads, whence the necessity for the relatively large expenditure of the time and money to secure them. Should the proposed railroad be one of great magnitude which will involve the expenditure of large sums for its installation, it is best to extend the observations over both the summer and winter months, as by so doing a more reliable average will be obtained.

Having now the actual passenger traffic business between each of the towns and the termini, as well as the local traffic between each of the towns, an estimate is made of the probable increase of traffic due to the increased facilities. Valuable statistical data relating to such increase

will be found among the list of references given in Appendix II. Upon three branches of the New York, New Haven & Hartford railroad which were changed from steam to electric systems the following results were obtained:

Comparison of Passengers Carried Per Annum upon Changing from Steam to Electric Operation.

NAME OF ROAD.	Passengers carried per annum operating by Steam	Electric
Nantasket Branch	304,292	702,419
Highland Division	387,695	1,060,617
New Canaan Branch	98,302	184,728

The systems cited above were, at the time these results were obtained, operating hourly and half-hourly schedules. The difference would undoubtedly be much greater with shorter headways; these figures, however, show nearly 100 per cent. increase as a minimum and about 270 per cent. increase as a maximum.

An estimate should now be made of the passenger traffic which will come to the new road. Let there be seven towns, as A, B, C, D, E, F, and G, including the termini. Determine upon the average fares between each place, and let A′, B′, C′, D′, E′, F′, and G′, be the respective populations of which A is the main or principal terminus. Let the estimated rides per capita from G to A equal N rides per annum, and the rate of fare between A and G equal R, then $G' \times N \times R = S$, which is the revenue which will accrue on account of the community of interest between G, the minor terminus, and A, the principal terminus. Proceeding in this manner for each town or population center, we obtain the total estimated revenue. As a concrete instance will be more impressive, attention is directed to Tables VI and VII showing computations of this kind, which the writer worked out for the New York & Port Chester Railroad.

Table VI is computed from data upon the earnings per capita taken from interurban statistics, which data were,

however, not used until the existing railway earnings per capita for the case in hand had been determined by ascertaining the existing business. The railroad earnings of places relatively remote from a large city are generally greater per capita for interurban roads than those of the nearer places.

TABLE VI.

Estimates of Earnings on Population Basis.

BETWEEN.	Population Carried per Year.	Average Fare per Trip.	Annual Income.
Port Chester and New York	7,000×120	15 cents	$126,000
Harrison, Rye and New York,	2,000×120	15 cents	36,000
Mamaroneck and New York	5,000×120	12 cents	72,000
New Rochelle, Larchmont and New York	20,000×150	10 cents	300,000
New Rochelle and Port Chester	30,000× 60	5 cents	90,000
Mt. Vernon, Pelham and New York	28,000×150	6 cents	252,000
New Rochelle and Mt. Vernon	35,000× 30	5 cents	52,500
Mt. Vernon and Port Chester	62,000× 20	7 cents	86,800
Bronx and Mt. Vernon	100,000× 50	5 cents	250,000
Annual summer and recreation business of the road	1,500,000	15 cents	225,000
Total passenger income per year			$1,490,300

The estimates of the earnings were made after a careful study of existing conditions in the territory to be served by the New York & Port Chester Railroad. These investigations extended over many months and had for their objects:

1. A careful study, after personal observation, of the habits of the people along the line; that is, ascertaining how, when, and where they traveled.

2. The existing inducements which would cause people to travel between the various cities and towns.

3. Ascertaining the occupations of the people and the probable stability of their employment.

4. Examination of the national censuses, as well as of the various ward, precinct, and school censuses.

5. Personal observations at the various points at which

the public boarded trolley cars, at all hours of the day and night for many months, to count and ascertain the amount and division of the existing travel.

A careful study of the business of the existing trolley and elevated roads in the district was made, as well as of the nearest existing approximations now obtaining elsewhere, and all data thus derived were plotted, and therefrom the deductions herein shown were drawn.

It was found that this estimate contemplates carrying the population served approximately one hundred (100) times per year. The business will include 18,000,00 fares per annum. As these 18,000,000 fares are based upon approximately 4,500,000 car miles, it will be seen that there must be carried but four passengers per car mile; 18,000,000 divided by 365 = 49,300 passengers per day of 398 trips, or an average of 124 passengers per complete trip of about 22 miles. There are 22 local stations and 12 express stations, which would give, on an average, 6 passengers per station per trip for the local service, and 10 passengers per station per trip for the express service.

TABLE VII.

Estimates of Earnings on Per Capita Basis by Dividing Territory Into Zones.

BETWEEN.	Population.	Earnings per Capita.	Total.
Port Chester and New York	8,000	$15 00	$120,000
Harrison, Rye and New York	2,000	15 00	30,000
Mamaroneck and New York	5,000	15 00	75,000
New Rochelle, Larchmont and New York	20,000	12 00	240,000
Mt. Vernon, Pelham and New York	30,000	10 00	300,000
New Rochelle and Port Chester	30,000	3 00	90,000
New Rochelle and Mt. Vernon	45,000	3 00	135,000
Mt. Vernon and Port Chester	80,000	1 50	120,000
Port Chester, Bronx and Mt. Vernon	100,000	3 00	300,000
			$1,410,000

Table VII was compiled upon the zone system and for the purposes of checking the results given in Table VI. Both methods can be used and should be in all cases of

this kind where a careful study of the question of probable traffic is important. The figures obtained differ slightly from those reached on the population basis but approximate so closely as to afford a satisfactory check.

In arriving at the probable earnings per capita, per annum, in Table VII, a careful study was made of the average railway fare expenditures per capita as they now exist in this territory, that is, the approximate amount of money paid to the existing steam and trolley roads by the residents of the different zones into which the district was divided for this purpose. In following out this method the intersection of One Hundred and Thirty-second street and Willis avenue was taken as the center, and circles with One Hundred and Thirty-second street and Willis avenue as a center, were drawn, the radius of each circle being one mile greater than the other. In this way 25 circles were obtained. Had the circles simply been carried to the State line, but 23 would have been obtained. Inasmuch, however, as there is quite an extensive population immediately beyond Port Chester in Connecticut, all of which will have easy access to this road by using the existing trolley roads for a short distance, the Connecticut population was taken into account for a distance of three miles from what would be the end of this road. The population for one-half of a mile on each side of this railroad was obtained for each of the zones, that is, the distance between any two consecutive circles, and the riding data of this population determined. For the purpose of arriving at this information, a careful count during the summer and winter was made for a period extending over six months, of the number of passengers on the trolley cars at different points in this territory, as well as the number of people using the steam road at each of the stations in the territory under consideration. This information was obtained in the way already described in the first part of this chapter.

When it had been obtained, a series of curves were plotted, showing the relations between receipts per capita and

population served for different periods, and localities or zones. From the curves so determined, the figures for the receipts per capita given in this statement were summarized. Of course the estimated earnings per capita given in this summary are less than the results actually obtained, as the figures given are those estimated for the New York & Port Chester Railroad portion of the business only.

TABLE VIII.

Statistics of Large City Properties.

	Miles of Track.	Population.	Gross Receipts.	Gross Receipts per Mile of Track.	Gross Receipts per Capita.
Interurban Street Railway Co., New York	403	2,050,600	$20,634,548	$51,202	$10 06
Philadelphia R. T. Co., Philadelphia, Pa..	475	1,293,697	14,006,915	29,492	10 98
Brooklyn R. T. Co., Brooklyn, N. Y.......	523	1,166,582	12,510,622	23,921	11 94
Boston Elevated Ry. Co , Boston, Mass...	387	744,062	11,060,385	28,58[illegible]	14 88
Pittsburg Railways Co., Pittsburg, Pa....	401	a750,000	8,276,565	20,640	11 03
Chicago Union Traction Co., Chicago, Ill..	303	1,698,575	7,825,120	25,825	8 35
St. Louis Transit and Suburban Co's......	455	a750,000	7,051,244	15,497	9 40
Chicago City Railway Co., Chicago, Ill....	219	1,698,575	6,367,358	29,075	8 35
United Railways of San Francisco, San Francisco, Cal..........................	244	a375,000	5,553,904	22,762	14 81
United Rys. & Electric Co., Baltimore, Md.	354	508,957	5,041,275	14,241	9 90
International Ry. Co., Buffalo, N. Y......	353	a500,000	4,426,675	12,540	8 85
Twin City R. T. Co., Minneapolis, Minn....	255	366,850	3,591,549	14,084	9 80
Detroit United Railway, Detroit, Mich....	380	b303,120	3,501,754	9,215	11 55
Cincinnati Traction Co., Cincinnati, O....	210	325,902	3,315,751	15,789	10 17
Milwaukee Electric Railway & Light Co., Milwaukee, Wis.........................	146	285,315	2,302,514	15,770	8 08

a Local estimate of city and suburbs 1903. b Local estimate 1901.

The above Table VIII shows some of the results which now obtain upon a number of systems operating in and about various large cities of the United States. They are all city systems, and with the exception of the Interurban Street Railway Company, of New York, all trolley roads. In most cases the figures for traffic are for the fiscal year 1902, while the population, unless otherwise indicated, is for 1900. The population given is that of the city in which each company operates. The column of gross receipts gives the entire re-

ceipts from passengers of the respective companies, including the receipts from branches extending outside of the city limits, so that the "gross receipts per capita" are in some cases slightly higher than they would be if they showed the receipts of the actual population served. The Brooklyn and Boston figures include the receipts from the elevated lines in those cities, as these systems in each case are operated in conjunction with the surface systems, and their receipts cannot be separated. Where there are two or more companies in the same city, the "gross receipts per capita" show the gross receipts of all of the surface street railways in the city.

In cases where there are no existing steam railroads serving the population to be connected by the electric railway, it is advisable to count the traffic by vehicles and stages between the different centers of population for periods sufficiently long and at proper intervals to give a fair annual average. From this information and by comparisons with the traffic of existing roads in similar conditions a fairly satisfactory estimate can be secured. In such comparisons the "population served" may very properly be considered to be that residing within about 1½ miles on each side of the proposed line, in cases, of course, where there is no other railway serving them. The entire population of large terminal cities, as has been already said, should not be added to the total sought, as all the residents of such city will not be probable patrons of the railway. In making per capita comparisons of this kind between a proposed and an existing railway, it is often better, where both have a large terminal city, to leave this city out of account in both instances. An even better plan, where the riding between stations on the operating road is known, is to make the comparison on the zone system, as already described.

Thus far the method which should be followed in determining the probable gross passenger earnings only of any interurban system has been described. The matter of determining the gross passenger earnings has been gone into some-

what in detail, for the reason that upon roads of this character the passenger earnings at present are by far the greater portion of the total gross earnings.

In addition to passenger earnings, however, estimates should be made of the probable gross revenue which will be derived from the carrying of freight, express, and mail. The data now available on this subject are not very complete on account of the fact that this branch of the interurban business has not yet been developed and systematized sufficiently to be able to furnish accurate data. For any special case, however, the gross freight and express business can be worked out and determined by a process very similar to that used in determining the gross passenger revenue. The process consists, first, in ascertaining the amount of freight and express business coming into and going out by railroad of each of the centers of population (in cases where an existing steam road is doing this business), and then determining what proportion could be secured by the electric road. Should there be no existing steam railroad, the method of procedure would be to ascertain the total production and consumption of the territory proposed to be served, which would include, of course, products of all kinds, that is, agricultural products and manufacturing products. An estimate of the gross tonnage from every point along the line of the proposed road can then be made to the points at which the freight would probably be carried, such as some large city or some other connecting road.

In estimating freight traffic for towns where there is no existing road supplying the population, and, consequently, where no actual approximate railroad data can be obtained for the probable ingoing and outgoing freight receipts of any single or number of population centers, another way to proceed is to ascertain the population of each of the population centers, and then have recourse to statistical data published by the United States and other governments, showing consumption and production per capita for given localities.

From such data, an estimate can be made of the probable railroad tonnage for the proposed road. Such an estimate will, of course, show the tonnage which would accrue on account of a service, such as is now in existence around the country, that is, the ordinary steam railroad service. There is no doubt, however, but that the actual tonnage for an electric service operating frequent units would be greater than that enjoyed by existing steam roads. Instances often exist also where freight and goods are taken out and into a community by means of wagons plying to and from railroad centers distant anywhere from 5 to 10 miles from the community. Where such cases exist fairly accurate data can be obtained by ascertaining the business which is done by such wagon service.

The freight and express traffic of existing interurban electric roads has been shown by the experience of the interurban lines in Ohio, Michigan, and elsewhere, to be a profitable portion of their business and one which bids fair to develop enormously. It is difficult yet to obtain any satisfactory figures as to just what this business will amount to, but from the information available from the roads investigated, a fair present average on a good road shows that it is now from $500 to $1,000 per annum per mile of single track, depending upon local conditions and the extent to which the freight and express business has been sought and developed. There is no doubt that the same reasons which have developed the passenger business on electric lines, that is, short headway, will be and is a large factor in developing the freight and express business. With steam railroads the object is to make every freight train unit a self-supporting or paying unit, which is also, as is well known, the process sought to be followed by steam roads in their passenger business. Steam railroad operating economy now lies in the direction of long trains, or in other words, in long headways, and the tendency of modern steam railroad economy is toward building larger and heavier freight engines, and cutting down grades and eliminating curves so as to reduce the cost of the "ton-mile," etc.

5

In the case of electric roads the unit at present is not the ton-mile, but the car-mile, and there is practically no economy to be gained by running long trains. It has been demonstrated that passengers can be carried for far less per mile on interurban roads paralleling steam roads than the steam roads have been able to carry such passengers for. This condition is due to the fact that electric roads operate single cars or trains at frequent intervals for the reason already pointed out, and increase the "riding habit." The same law holds good in freight transportation. If the commercial interests

EXPRESS AND FREIGHT CAR OF THE SOUTHERN OHIO TRACTION COMPANY.

of a community realized that they could replenish their stocks upon a day's notice, they would cease laying in supplies of goods of such quantity that would last them a week or ten days, or possibly two weeks, as is now the case, and through the saving thus secured in insurance, interest, warehouse handling, etc., could afford and would pay a higher rate to the electric road for the "express" handling of goods

than that now paid to steam railroad companies. In other words, a rapid and frequent train service, such as electric roads can give, will not only materially increase the freight and express business, but by eliminating the economically nonproductive conditions now existing between the producers and the consumers will develop a most important landmark in political economy.

There is no doubt that such relatively high-speed, high-class interurban electric railroad systems as I have been and am essentially considering in this book, and which are to play an important part in transportation economics, will soon attain gross passenger earnings of from $12,000 to $15,000 per mile of single track per year and more, and will also attain additional earnings from freight, express, and mail business of from $2,000 to $3,000 per mile of single track per year. I refer especially to roads operating at schedule speeds of from 30 to 40 miles per hour and more, on private rights of way, connecting large centers of population and having stations or stops from a quarter of a mile to a mile or more apart, running cars at frequent headway, and when designed and installed by competent railway experts, fitted by experience to judge of the present and future economic activities of given conditions, and with special reference to the economic considerations set forth in Chapter XVIII. Already some of the better classes of electric interurban roads are obtaining $10,000 to $12,000 per mile of single track per year from passengers, and $1,000 to $1,200 per mile of single track per year from freight and express, and this in cases where the whole or the major part of the tracks are on public highways, and where, consequently, the schedules are limited to 16 or 20 miles per hour, which, as I have shown elsewhere in this book, is a perpetual handicap to interurban high-speed railroads so designed and installed.

CHAPTER VII.

ESTIMATE OF PROBABLE OPERATING EXPENSES.

The next step is the determination of the costs of operation and maintenance, as well as the amount of the fixed charges.

In connection with electric railroad operation, an unfortunate habit has developed of estimating the annual costs of operation and maintenance as a percentage of the gross receipts. Estimates of this kind really mean nothing and have no real value even for comparisons. They are even dangerous when used in such computations and determinations as discussed here, on account of the difference in conditions, such as number of cars operated, length of route, headway, average distance each passenger is carried, and tributary population per mile of track, and especially relative receipts, etc.

In order to use the percentage of the gross receipts method in making comparisons, some of the details of operation should accompany the statement of the percentage of gross receipts required to operate the road. Such accompanying details should show:

1. The gross receipts.
2. The car mileage operated daily and yearly.
3. The average daily mileage per car.
4. The total number of miles of single track operated.
5. The amounts annually expended for maintenance of way and structures, and maintenance of equipment, and the amounts per car mile for these items.
6. The physical condition of the property.
7. The capital liabilities and fixed charges.
8. Traffic density or passengers carried per car mile.

Of two roads having approximately the same amount of track, the one operating at the larger percentage of the gross receipts may have the larger net. Suppose one of two such roads to have gross receipts of $1,500,000, and to be operating at 60 per cent. of its gross receipts. Suppose the second

of the two to have gross receipts of $900,000, and to be operating at 50 per cent. of its gross receipts. In the first case the net will be $600,000 while in the second case it will be but $450,000. If each has approximately the same amount of track, the fixed charges will probably be nearly the same. This instance will show the necessity for additional detail if such data are used.

The only safe way to proceed is to determine the detail cost of each item entering into the total cost of operation. The subject is generally divided into four subdivisions, by existing steam and some electric systems, as follows:

1. Cost of maintenance of roadway and structures.
2. Cost of maintenance of equipment.
3. Cost of conducting transportation.
4. General expense.

Any item of operating costs can be classified under one of the four heads above given. I find it more satisfactory to use the following subdivision for electric systems:

1. Cost of train crews.
2. Cost of station men, such as ticket agents, etc.
3. Maintenance and inspection of cars and equipment.
4. Maintenance of roadway and structures.
5. Cost of operating main power station, including fuel, oil, waste, etc., and labor and repairs.
6. Cost of operating rotary stations.
7. Salaries of officers and clerks, etc.

Each factor of each of the foregoing items should be carefully computed and the total cost of operation and maintenance thus ascertained. This is the only safe and true way of arriving at a proper conclusion.

The fixed charges include the following items:

1. Interest on bonds or other interest-carrying obligations.
2. Cost of leaseholds or rentals.
3. State and other taxes.

Taxes are often placed under the head of operating expenses.

They are sometimes determined as a percentage (from 2 to 5 per cent.) of the gross receipts.

For the reasons specified above, detail comparisons with similar conditions of existing roads, as with the question of gross receipts, offer the best method of determining the operating expenses. The reader is recommended to use in all cases the latest figures obtainable, as given in the reports of the several properties themselves or in financial annuals like "American Street Railway Investments," reports of the State Railroad Commissioners of New York, Massachusetts, etc.

The detailed estimate of the operating cost of a proposed electric railway, as recently prepared by the writer for a 96-mile line, can be made up somewhat as follows:

Details of Operating Cost of a High-Speed Interurban Electric Railway.

Length, 96 miles of main single track (about 24 miles of roadway).
124 local trains each way, trains of one car.
74 express trains each way, trains of two cars.
4,500,000 car miles per annum.

A. Train crews	$84,080 89
B. Station men	80,300 00
C. Maintenance and inspection of cars and equipment	90,000 00
D. Maintenance of roadway and structures	96,000 00
E. Cost of power	253,116 55
F. Rotary stations	16,425 00
G. Salaries of officers	50,000 00
	$669,922 44

A. Train Crews.

124 local trains each way per day; single trip time, 49 minutes.

74 express trains each way per day; single trip time, 31 minutes.

$124 \times 2 \times 49 \div 60 = 202.5$ car hours per day of 24 hours for local service. Local service to consist of one car having a crew of:

1 motorman at \$3 per day of 10 hours;
1 conductor at \$2.50 per day of 10 hours;
Total, \$5.50 per day of 10 hours; or \$0.55 per car hour.

$202.5 \times \$0.55 \times 365 = \$40{,}751.875$, cost of local train service per year.

$74 \times 2 \times 31 \div 60 = 76.4$ train hours per day of 24 hours for express service. Express service to consist of two-car units carrying the following crew:

1 motorman at \$3 per day of 10 hours;
1 conductor at \$2.50 per day of 10 hours;
1 conductor at \$2.50 per day of 10 hours;
\$8 per day of 10 hours, or \$0.80 per car hour.

$76.4 \times \$0.80 \times 365 = \$22{,}308.80$, cost of express train service per year.

$\$40{,}751.875 + \$22{,}308.80 = \$63{,}060.675$, total cost

Adding one-third of above for extra men — \$21,020.22 — we have $\$63{,}060.675 + \$21{,}020.22 = \$84{,}080.895$, total cost trainmen, etc., per year.

B. Station Crews.

22 stations using 5 men each = 110 men at an average of \$2 per day each = \$220 per day.

$\$220 \times 365$ — per year = \$80,300.

C. Maintenance and Inspection of Cars and Equipment.

Total car mileage equals 4,169,760 per year, and allowing for extra occasions will equal 4,500,000, at \$.02 per car mile = \$90,000.

D. Maintenance of Roadway and Structures.

96 miles single track, including sidings, etc., at \$1,000 per mile per year = \$96,000.

E. Cost of Power.

Local service, 124 × 2 × 21 = 5,208 local car miles per day.

At 160 watt hours per ton mile = 270,816 × 160 = 43,330,560 watt hours per day for local service.

Express service, 74 × 2 × 21 = 3,108 train miles per day for express service.

3,108 × 2 = 6,216 car miles per day.

6,216 × 52 = 323,232 ton miles per day for express service.

323,232 × 130 = 42,020,160 watt hours per day for express service.

42,020,160 + 43,330,560 = 85,350,720, total watt hours per day of 24 hours, or 85,350.7 kw. hours.

Add 18 per cent. for loss from main station to third rail and 5 per cent. for heating and 2 per cent. for lighting; 25 per cent. = 21,337.7.

85,350.7 + 21,337.7 = 106,688.4 kw. hours. This at \$.0065 per kilowatt hour = \$693.47 per day for producing the power and maintaining the power station.

365 × \$693.47 = \$253,165.55 per year.

Power Station Detail.

1	chief engineer, per day	\$10 00
3	assistant engineers at \$5 per day	15 00
30	oilers at \$2.50 per day	75 00
3	switchboard men	10 50

3	electric helpers	$7 50
6	cleaners	9 00
6	condenser men	15 00
	machinist and two helpers	9 00
24	boiler men at $2.50 per day	60 00
	boiler cleaner and two helpers	6 00
4	laborers	6 00
		$223 00

Coal at $2.40 per ton; 106,684 kw. at 2¾ lbs. coal per kilowatt = 293,381 lbs., or 146.69 tons coal per day.

146.69 × $2.40 = $352.057, cost of coal per day. $223 + $325.057 = $575.057, cost of labor and coal per day of 106,684 kw. hours.

$575.057 ÷ 106,684 = $.00538 per kilowatt hour. $.0065 — $.00538 = $.00112, for repairs and maintenance per kilowatt hour.

In arriving at the costs of the maintenance of way and structures for the railroad considered in the foregoing estimate, the following figures were taken as the annual cost per mile of single track:

Renewals of rails	$256 00
Renewals of ties	108 00
Renewals of ballast	35 00
Labor	364 00
Repairs and renewals of fencing	25 00
Total	$882 00

There will be several other minor items entering into this cost, such as the cost of occasionally changing the switches, the cutting of weeds, and maintenance of the block-signal system, which, however, would not materially augment the

above sum. In order, however, to be on the safe side of this matter, I have taken $1,000 per mile as the cost of maintenance of way and structures, and have taken a total mileage of 96 miles.

The cost of the rail splices, bolts, and spikes is $5,092 per mile of single track.

The cost of the ties per mile of single track is taken at $1,848.

The steam-trunk lines of the United States estimate the life of their rails for main-line service at about 15 years, after which they are replaced, and the old rails used for sidings and other light and intermittent service. A service of 15 years on trunk lines using the heaviest steam engines is certainly equivalent to a service of 20 years for conditions such as will prevail on the average high-speed electric line, using rails as they are now made. A life of 20 years is equivalent to 5 per cent. for renewals.

Applying the same reasoning to the item of tie renewals, and allowing 6 per cent. for this item, will equal to $108 per mile of single track per year.

Five per cent. per mile of single track per year has been allowed for renewal of the rock ballast.

The cost of the labor item has been arrived at by dividing the road into sections 3 miles in length, and allowing 5 trackman, at a total of $9 per day, and 2 linemen, at a total of $5 per day per section. Sections 3 miles long of 4 tracks each, or 12 miles of single track = $14 per day or $14 × 312 = $4,368 per 12 miles per year, or

$$\frac{4368}{12} = \$364 \text{ per mile of single track per year.}$$

In the foregoing figures relating to the cost of power, as shown at "E," the weight of the loaded motor car is taken at 52 tons, divided as follows: 25 tons for the weight of the car and trucks; 17 tons for the weight of the equipment; 10 tons for the weight of the passengers. This is probably

slightly in excess of that which would ultimately maintain. The first sets of run sheets constructed showed for the local service an energy consumption in watt hours per ton mile varying between 138 and 160. The larger figures were taken for the purpose of being on the safe side and are used above. After the conditions had been thoroughly studied for some months, the energy consumption in watt hours per ton mile, for both the local and express schedules was very much reduced.

In the foregoing illustration of the method pursued in arriving at some of the operating costs of the New York & Port Chester Railroad, it will be noted that almost all of the figures are essentially original, that is, they are not based upon car mileage or other data obtained from the operating records of other railroads. The reason for this is that at the time these figures were made, there was absolutely no other railroad in existence constructed according to the plans of construction of the New York & Port Chester Railroad Company, or operated as it was proposed to operate this road. After completing the estimate shown above, I deemed it advisable, if possible, to make an estimate based upon some operating conditions. The nearest approach which could be arrived at at the time was that of an elevated road in a large city, operating at a schedule speed of about 16 miles per hour. For the purpose of comparison, in what follows, the elevated railroad will be referred to as the Elevated Road.

From the official records of the Elevated Road, the operating costs per car mile for the various items were worked out. These costs are as follows:

(1) Train crews, telegraphers, couplers, and yard men	$.0237 per car mile.
(2) Station men, agents, porters, and laborers	.0072 " " "
(3) Maintenance, inspection, and up-keep of cars, trucks, and motive power	.0125 " " "
(4) Repairs of structure and roadway	.0065 " " "
(5) Cost of power for transportation, lighting, and braking	.0123 " " "

(6) Rotaries (none used).		
(7) Miscellaneous expenses, supplies, etc.	$.0021	per car mile.
(8) General expenses, salaries, etc.	.0084	" " "
	$.0727	" " "
(9) City tax on cars and other taxes	.00648	" " "
(10) Legal expenses and injuries	.00532	" " "
	$.0845	" " "

For the purpose of making the comparison, or, rather, of arriving at the operating cost of the Port Chester Road upon a car mile basis, each of the foregoing items was considered in detail as follows:

It was concluded that the New York & Port Chester Road would use a maximum of about 9 kilowatt hours per car mile at the central station, as against about 2 kilowatt hours per car mile at the central station which the Elevated Road was using — an excess of 7 kilowatt hours.

At $.0065 per kilowatt hour, there would be 4.55 cents excess cost per car mile for power for the New York & Port Chester Road, as compared with that of the Elevated Road.

The depreciation of the roadbed for the Port Chester Road should not be any greater than that for the elevated road.

The cost of maintenance of motors and cars will be increased about 1 cent per car mile, on account of the use of larger motors, etc.

The cost of the wages of trainmen, etc., per car mile, will be less for the Port Chester Road, on account of the increased schedule, the difference being about one-third — or about $.0076.

The cost of the operation of the rotaries is an extra to be added. This additional cost is estimated at $.0037 per car mile.

The general expenses should not be increased.

For unknown expenses and contingencies, there was added $.0075 per car mile.

Apply these changes to the New York & Port Chester Road, as follows:

By excluding items (9) and (10) of the table shown above, we find that the cost of operation per car mile for the elevated road is	7.27	cents.
Add additional cost, for Port Chester road, for power	4.55	"
For maintenance of cars and motors	1.00	"
For rotaries	.37	"
For unknown expenses and contingencies	.75	"
	13.94	"
Subtract — difference for train crews, etc.	.76	"
Balance	13.18	"
Add — for legal expenses, injuries, and taxes (same as elevated road)	1.18	"
Total per car mile	14.36	"

By comparing the results arrived at in the manner last shown with the figures obtained by determining the detailed cost of each and every item as shown in the preceding estimate of operating costs, it will be noted that a fair check is obtained. It will be noted, however, that the operating costs obtained by the detailed method as shown are greater than those obtained by the comparative method last shown, which only serves to bear out the statement made elsewhere in this book that the method of determining operating costs for any given set of conditions by comparing them with other as nearly as possible similar set of conditions, is not, by any means, always reliable. I desire to repeat here again that the only proper way to do is to determine the detailed cost of each and every item for the proposed conditions. The results may, of course, be checked by comparison with as nearly as possible similar conditions as was done above.

CHAPTER VIII.

THE FINAL SURVEY.

Preparatory to the preparation of the ultimate specifications, the entire line must be finally inspected and the location, length, and kind of each highway or other crossing determined, together with all culverts and drainage systems. A detail of each highway, railroad, water-way, or other crossing, whether arch or subway, together with each culvert, must be prepared. Such details show the quantities of all materials of each of such structures, together with the cost of construction.

If necessary the field parties are again sent out to take cross-sectional measurements at such intervals as will enable a final and accurate estimate to be made of the quantities of earth and rock cut and fill. The accuracy of the earth and rock work estimates will depend not so much upon the number as upon the positions of the cross-sections taken. Soundings or borings are also obtained to determine the nature of the soil and the approximate locations of the earth and rock, and the respective quantities of each.

As a general rule, the railroad companies, for such cases as herein indicated, let a contract to some individual or company to furnish them with the data relating to the details of the soil beneath the surface of the earth, for the distance desired, equal to the depth of the proposed grade line below such surface. Such contracts provide that the contractor shall make borings or soundings at points indicated by the railroad company along the line of its route. The contract provides that the contractor shall produce a sectional sample, to scale, for each of such points. The method of procedure consists in boring into the ground and in taking a sample of each of the kinds of rock and earth met with in the boring, and noting the depth and extent of such rock or earth. A glass tube is then taken and

the earth or rock, as the case may be, placed in such a glass tube in the exact relative positions in which it was found in boring. The distance from the top part of the earth or rock in the glass tube to the bottom is, to scale, the distance from the surface to the bottom of the boring. Each of the subsoil materials is represented in this glass tube to scale. Such contracts are generally given at so much per foot of boring. The price ranges from 10 to 25 cents per vertical foot. The contractor furnishes all the material and men for the work.

After the final line has been mapped out it is located on the ground. Line stakes, which are wooden sticks about 1½ inches square and 15 inches long, pointed at one end, are carefully set. All alignment curves are finally run and staked. All fences or other property boundaries are accurately measured and taken together with the names of the property-owners.

The stations or stopping places are finally determined.

The run sheets are compared again with the final survey and are altered to accord with it, or if necessary the route is altered to secure a better run sheet as each, of course, depends on the other. A slight and almost immaterial change in the route will occasionally improve the run sheet and *vice versa.* The engineer at this time will settle the details of the proposed schedules, which have, up to this point, been determined only approximately, such as length of stops at stations, laying over time at termini, permissible limits of acceleration, maximum speed and its duration, and, where required, the maximum current, as well as the square root of the mean square of the current for the different runs.

This last item, that is, the square root of the mean square of the current, is essentially one of the details of design. Its value as an element to be taken into consideration is disputed. It has no intrinsic value to the consulting engineer. In determining upon a motor equipment, the en-

gineer will do best to rely essentially upon the manufacturers' data and guarantees, and upon the acceptance tests over an equivalent run, which the engineer should lay out and specify. The manufacturers are always in a better position to determine what factors shall enter into the design of a motor than the consulting engineer, who is really only concerned with the matter of performance.

With the schedules or time-tables plotted on cross-section paper, as already described, the load diagram is ascertained for the purpose of finally determining the details of the power-houses, substations and transmission systems.

A load diagram can be obtained by calculating the varying loads at different periods of the 24 hours, as shown in Chapter V, and plotting the results. Where load curves are calculated, an average, instead of an actual run is taken. Motors, equipment, gear ratio, and energy consumption may also be conveniently determined by taking average runs.

Plates I, II, and III show typical individual run sheets between certain stations. As will be noticed, typical data of each run is given, and on the total sheet similar data should also be shown for each total run curve. Such data are determined by integration or computation after the power curves or run sheets have been obtained, and consist of:

1. Distance.
2. Ton miles per car.
3. Total kilowatt hours per run.
4. Kilowatt hours per car mile.
5. Watt hours per ton mile.

There is a point to which attention should be called in connection with these run sheets, and which will appear more in the detail in Chapter XIII. This is, that the actual initial, or accelerating line is not the smooth even line shown on the total run sheet, Plate III, or as shown on the diagrams, Plates I and II. The actual line is serrated, while the lines shown in the diagrams are the average lines. They are,

however, accurate to within such a small percentage as to make their use entirely proper. It should also be noted that the line of braking cannot be straight, as shown. It is also irregular in shape. The lines shown as the braking lines are also the lines showing the average effect. It is the lines showing the average effect that are always used.

The maximum current, and all currents obtained by constructing the load diagrams, are those that are required at the track, to which must be added the losses which will occur between the track and the substation, in order to determine the capacity of the substations and the sizes of the units in them.

To the energy required at the substations must be added the transmission losses between the substations and the main or generating station, to determine the capacity of the main station, and the sizes of the units in it.

The conductors used for conveying the energy from the main station to the substations may be either aluminum or copper. Aluminum is very widely used where the wires are carried on overhead lines; copper is invariably employed where the transmission is done by burying the conductors, as in the case of cities and towns.

The elements, controlling the determination of the size of the conductors for transmission systems, may be briefly referred to at this point.

In the case of alternating current systems there is to be considered, in determining the size of conductors, in addition to the ohmic resistance, the element of reactance, which in the case of high frequencies may be controlling. The theory of the effects of reactance, together with its components, is fully set forth in text-books on the alternating current, and will not be taken up here as it only enters into the determination of the size of the conductors connecting the main station with the substations.

The direct current transmission system is determined by dividing the road into sections, each a mile or more in length,

depending upon the load which will be on any section and substation. Each section is insulated from the ones adjacent to it, for the purpose of providing against a derangement of the entire system in the event of an accident or a short circuit at any given point or points.

The method of procedure is to make a diagrammatic representation of the entire line to scale. All of the cars, during the times or periods of maximum service should then be located on this diagram, at their proper relative distances apart on the diagram. With the cars so spaced the road should be divided into sections. The loads and their distances from the feeding substation will, in this case, determine the length of each section. The number, position, and, consequently, the degree of motion of the cars of each section, during the times of maximum service, will determine the amount and distribution of the maximum current required for each section. The next step is to ascertain from the distribution of the current required for each section, the point which is known as the electrical center of gravity of the section, and to this point the feeder or feeders from the proper substation should be run. Ohm's law and wiring-tables will enable any one to determine the cross-sectional area of the electrical conductors for any determined loss from the substations to the point of tapping any section. The modification of Ohm's law to be used is expressed by the formula:

$$A = K \times \frac{C \times L}{E}$$

Where

A = cross-sectional area of the current conductor in circular mils.

C = current in amperes.

E = loss in volts.

L = total length of circuit, that is, the distance to the point of feeding plus the return distance.

K = constant depending upon the conductivity of the conductor.

The formula, as commonly used, is expressed as follows:

$$\text{circular mils} = 21.12 \times \frac{D \times C}{E}$$

Where

D = simply the distance from the substation to the feeding point or the distance one way.

This is for copper wire having a conductivity of 98 per cent.

For aluminum the formula is the same with a proper value for K.

The resistance of 1 circular mil. foot of aluminum having a conductivity of 51 per cent. at 65 degrees F. = 17.225 ohms. The formula for aluminum becomes:

$$\text{circular mils} = 34.45 \times \frac{D \times C}{E}$$

The maximum losses between the main station and the substation should not be over 6 or 7 per cent. The average maximum losses between the substations and the car-collecting devices should not be over 12 per cent. In Chapter V attention has been called to the necessity of providing for fluctuations which vary from 20 to 33 per cent. or more.

The best practice of to-day for the power-house installation for an extended interurban system consists of a high-tension alternating current central station plant, the potential of distribution at the generators ranging between 10,000 and 30,000 volts. In some cases of very high voltage the generator voltage is raised by means of step-up transformers, instead of being developed directly in the generator.

The energy is then transmitted to the substations at the high voltage, where the voltage is reduced by means of step-down transformers, from where it passes through an alternate current switchboard, and is then carried to the alternate current side of the rotary converters, where the energy

is transformed into direct current and taken from the commutator of the rotary converter to the direct current switchboard at 650 to 750 volts, from where it is carried to the car-collecting devices through copper or other conductors.

In the event of a commercial alternating current motor being brought out, the alternating current generating system here described could be used by simply replacing the rotary converter substations, with static transformers placed along the line at properly determined intervals. The only financial loss in the event of the development of an alternating current commercial motor and system would be that involved in the motors and rotary converters, which will be comparatively insignificant.

An alternating current system has many desirable characteristics, among which are:

1. The ability to use much higher voltages and thereby effect a considerable saving in the cost of the transmission systems.

2. The use of induction motors, the simplicity of which are very marked, eliminating, as they do, the necessity for commutators. As they consist of nothing more than a compact revolving mass of iron and copper, their mechanical construction can be made all that could be desired. At the present time induction motor control apparatus has not been brought to a desirable state of simplicity, but there is no reason why admirable results should not be expected in the very near future.

In the case of direct current the voltage is limited by the commutator. At the present time the large manufacturing companies do not feel that they would care to guarantee a direct current railway motor, operating at a potential in excess of 700 volts. Again, a direct current substation will generally transmit the direct current economically for about a distance of from 8 to 10 miles on each side of the substations, for cases such as have been under discussion, the economical distance depending upon the car service or loads.

CHAPTER IX.

TRACK CONSTRUCTION AND SUPERSTRUCTURE.

The rail used in track construction for the class of electric roads which is being considered differs from that required by electric roads whose track or tracks lie in paved streets. In the latter cases the authorities generally require a rail to be used which will interfere as little as possible with vehicular traffic. The track for the high-class, high-speed interurban electric line does not differ materially from that required for the best steam railroad construction, except in the question of location, which has been thoroughly discussed in a previous chapter, bonding, and the use of the rail for the return circuit, both of which will be discussed later.

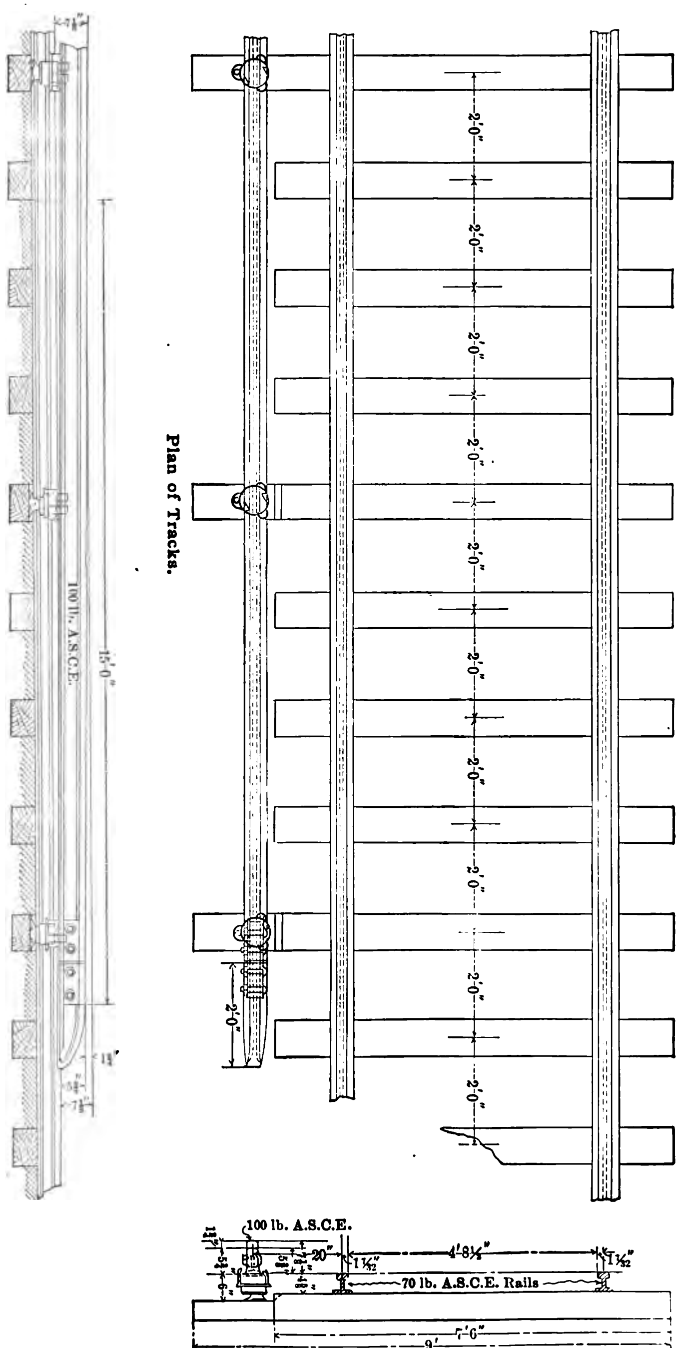
It is not the intention to take up minutely the questions of ballast, ties, rail-sections, and composition, rail-joints and other points in which an interurban electric railway track is similar to that used for steam railroad work. These subjects would require a book in themselves, and, in addition, there are many excellent treatises upon them. It might be stated, however, that as a rule the service imposed upon electric railway track is not so severe as that imposed upon a track for steam railroad service. The heaviest electric cars of to-day, with their load and equipment, do not exceed 50 tons in weight, and the absence of reciprocating parts which exist in steam locomotives makes the electric car much less wearing on the track than in steam railroad service. It is possible, for this reason, to use a lighter rail, and, as a rule, an 80-pound T rail is amply sufficient for the service. The matter of the proper width of the right of way for one, two, or four tracks, together with the determination of the proper slope of the earth in cuts or fills, is discussed in another chapter.

Proper ballasting is most essential for the purposes of drainage and for the additional purposes of preserving the

surface and alignment of the track. Practice differs as to the amount of ballast required, but from six to ten inches under the tie is usually ample if care is taken to have the ballast well tamped under and between the ties. In good practice, the ballast is brought up between the ties to the level of the top of the ties. Broken stone to pass through a two and one-half inch ring is the size usually specified. Gravel and cinders may be used, but are not as desirable as broken stone. It is always advisable in selecting ballast to choose one which will produce a minimum amount of dust in the operation of the road, and broken stone is the best material which can be used for this purpose. Where the ballast is deeper than six or eight inches, it is sometimes customary to lay the bottom course of larger stones to act as a foundation for the smaller ones. While this course has been adopted, it is certainly not to be recommended unless unusual care is taken in laying the bottom or foundation stones.

The standard tie on the New York Central Railroad is 7″× 8″× 8′, and very few of the larger steam roads use a tie smaller than 6″ × 8″ × 8′. At the present time, yellow pine ties are being very extensively used for straight track work, as are also cedar ties. Chestnut ties are also extensively used. The best tie for lasting qualities is the white oak hewed tie. Where pine or other ties are used for straight track work, white oak should always be adopted for curves, on account of the better holding power which a white oak tie furnishes for the spikes. While white oak ties are considerably more expensive than the others, their use will be found more economical in the end, especially for high-speed installations where the spreading of the rail will be a most serious matter.

Ties are spaced anywhere from 15 to 30 inches apart between tie centers, depending upon the service conditions of the road. Where a third rail is used, it is necessary to have about every fifth tie from six inches to a foot longer to carry the third-rail insulator. Third-rail ties are generally of oak



PLAN, SECTION, AND ELEVATION OF TRACK AND THIRD RAIL — SEATTLE-TACOMA INTERURBAN RAILWAY.

for the purpose of securing the necessary stability of the third rail.

Modern practice on both steam and electric railroads tends toward the use of a rail section known as the standard of the American Society of Civil Engineers, and which is characterized by a flat head with sides vertical or nearly vertical and with the following distribution of metal: Head, 42 per cent.; web, 21 per cent.; base, 37 per cent. In electric work the rails are now often laid in 60-foot lengths and tie plates are usually employed.

The following table gives the allowance for expansion in degrees F., at the time the rail is being laid, followed in standard first-class construction where a 70-pound rail is employed:

Degrees Fahrenheit.	Allowance Inches.	Degrees Fahrenheit.	Allowance Inches.
80	1/16	50	$\frac{1}{4}$
70	$\frac{1}{8}$	40	5/16
60	3/16	30	$\frac{3}{8}$

Tables showing the proper allowance for expansion for different temperatures can be found in any of the well-known engineering hand-books. The proper joint space for any set of conditions can also readily be calculated from data relating to expansion coefficients, etc., to be found in almost any work on civil engineering.

All interurban railway track should be bonded by a concealed rail bond to protect the bond from accidental or intentional injury. This construction requires the selection of an angle plate which will not wear down so as to chafe or wear out the head of the bond. Great care should be exercised in installing the bonds, as any slight oxidation between the face of the bond and the interior surface of the bond hole will create future trouble and expense. Bonding should preferably be done in dry weather and the bond holes should be freshly reamed before inserting the bond.

There is a variety of bonds on the market, any one of which can be rendered practically worthless by carelessness in installation, whereas almost any one of half a dozen different makes will give perfectly satisfactory results if properly installed. The chief desiderata in a bond after the most important qualification of good contact are area of contact and ample carrying capacity.

The proper length of angle bar depends upon whether the suspended or supported joint is used. Practice differs in this respect, but the suspended joint staggered is in the opinion of the writer the most desirable to use in high-speed service. With suspended joints the joint ties are usually from 8 inches to 10 inches apart, while with the supported joint, the joint tie is usually laid about 6 inches from the two adjoining ties.

The two end bolt holes in the rail are usually punched nearer the end in electric railway work than in steam railway track, and the bond holes are punched midway between the first and second bolt holes, counting from the ends of the rails. A number of special bridge joints, such as the "continuous," Weber, Churchill and Atlas have also been and are being used very largely in electric track construction.

Block signals are quite as important on high-speed electric railways as on steam railroads, but the type of signal usually used in steam railroad work is not entirely applicable to electric railway conditions. In steam railroad work the track is divided into sections, and the sections are insulated from each other, as are also each line of rails. As only a low voltage is used with the batteries which operate the block-signal system, no elaborate preparation has to be made for its insulation, the only precaution taken being that insulating blocks are inserted where the switch levers connect the rails of each track. The axles of a steam train on any section of track short-circuit the rails and thus operate the block signal, indicating that the section is occupied by a train.

With an electric railway line where the entire track has to be very carefully bonded and cross-bonded, an arrangement of this kind is not applicable. The only means available is to install a separate circuit, and on surface lines this is usually accomplished by some modification of the simple plan shown below. In this diagram, which indicates a

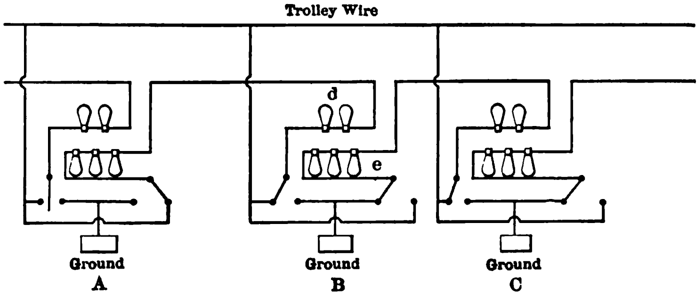


DIAGRAM ILLUSTRATING BLOCK-SIGNAL SYSTEM.

single-track line, A, B, and C are the turnouts. An auxiliary wire connects the two turnouts and has at each end a double-throw switch so that the line can be connected either to the trolley wire or to the ground. With a 500-volt line five lamps are used in series with this circuit, and these lamps are grouped so that the two lamps, d, are in, say, the upper section of the signal box at B, and the three lamps, e, are in the lower half of the same box. As drawn, the section B C is blocked, and the section A B is open, the blocking being indicated by the lamps burning, and the open section being indicated by the lamps dark. A car then traveling from C to B on reaching B clears the section B C by throwing down the switch controlling that block and closes the block A B by a movement of the switch controlling the lamp block. It can easily be seen that by this system the movement can be in either direction, that is, an open block can be closed from either end, and the cars do not have to pass alternately in each direction through the block. Modifications of this system have been

made by which the signals are operated automatically so that the car does not have to be stopped to provide for manual operation by the conductor.

The condition of block-signal systems, as they are now adapted to interurban electric railways, is not by any means satisfactory. The essential requisite, that is, reliability of operation, appears to be lacking. On a number of interurban electric railways, operating overhead trolley systems at relatively high speeds, the operations of the signals are affected by the trolley wheel passing under and contacting with a piece of metal attached to the trolley wire. Such systems generally operate fairly well throughout the summer months, but there appears to have been a great deal of difficulty with them during the winter months on account of sleet and snow. At this time, judging by the number of applications for patents for block-signal systems for electric railways, there appears to be little or no doubt that a satisfactory system will be forthcoming in the near future. In looking over the list of patents, one is struck by the thought and the ingenuity put forth to devise safe and reliable systems for the condition of single-track roads using turnouts. Some of the systems devised with this class of roads in view would, in all probability, be applicable to other conditions, such as double-track roads. It appears to me that such well-meaning inventors overlook the fact that the first requisite of safety in the operation of high-speed electric roads must be at least a double-track road, and that such inventors would do far better if they would devote their energies to the development of block-signal systems for double-track roads, which would probably not require nearly the ingenuity of some of the proposed single-track turnout systems, application for patents for which have recently been filed in the patent office.

Figures 1, 2, 3, 4, 5, and 6, on page 93, are a set of diagrams showing various arrangements of the "blocks," or sections of block signal systems. Diagrams 1, 2, 5, and 6

show the arrangement where each block or section is provided with an "overlap," the object of which is to let a train unit get well beyond a controlling signal before the signal will move to danger. The amount of overlap for any given installation will be determined by the maximum speed, the safe distance in which a train can be brought to a stop from the maximum speed and the headway of the train units.

Figures 3 and 4 show the arrangement of a block signal system where no overlap is used.

Notwithstanding the apparent advantages of overlap, there are many engineers who do not favor its use. The argument against its use generally is that it encourages careless running, for the reason that a train operator always feels that, should he pass a signal at danger, he has yet a considerable distance to go before he can encounter any other train.

Consider, for a moment, diagrams 3 and 4. The moment the train passes out of any block, as D, C, or B, both the signals at the entrance of the block next entered at once go to danger, while at the entrance of the block just vacated, the distance signal alone is at danger. It is well known that trainmen take liberties with "distance" or cautionary signals in the matter of speeds, which they do not take with danger or "home" signals. Inasmuch as the home or danger signal (in no-lap systems) acts just as soon as a car or train is opposite the signal, it is evident that a following train might not be able to avoid a disaster after seeing a danger signal on account of the train ahead being at rest practically at the signal intended to warn the train behind it.

There is no reason why as good discipline should not be maintained with an "overlap" system as with the "no-lap" system. An overlap system is simply giving the traveling public and the railroad company another chance against the possible inadvertence, recklessness, or carelessness of its men.

The fact that in some recent instances where bad wrecks have occurred, the existing *"no-lap"* systems have been changed to properly designed "overlap" systems is probably the best argument for the use of the overlap system.

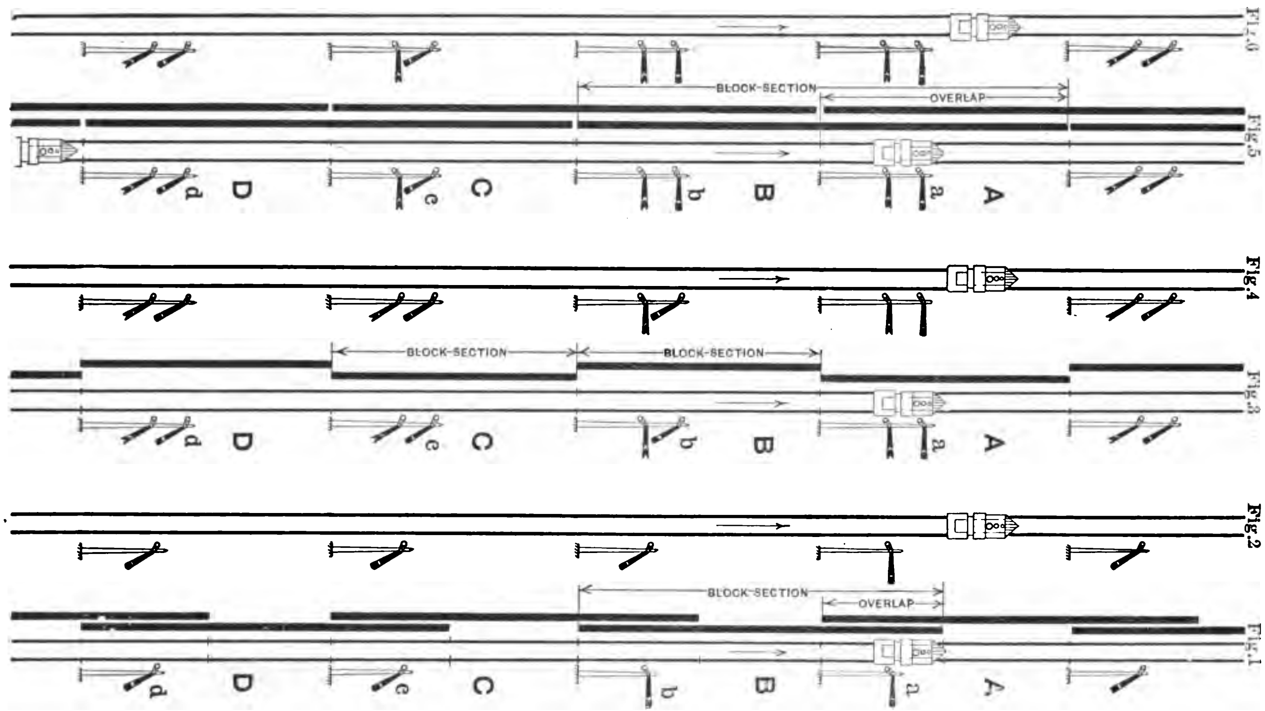


DIAGRAM SHOWING VARIOUS METHODS OF ARRANGING BLOCK SIGNALS.

The Boston Elevated Railway Company uses on its elevated lines a system somewhat similar to that used on steam railroads, and secures the extra circuit necessary by insulating one of the rails. This is permissible on an elevated railroad, because the carrying capacity provided by both rails is not necessary in the return circuit where the iron structure of an elevated railway is available for this purpose. The sacrifice of one line of rails on a surface road or some of the recently designed subway systems, is a serious matter, but appears necessary in the present state of the block-signal systems now obtainable. In some cases the sacrifice of one of the track-rails for signal purposes is impracticable. In Boston, the additional precaution has been adopted of providing, in connection with the block signals, an automatic stop, consisting of a small lever which is properly located near the track rails, and which is raised by the movement of the semaphore apparatus. If the signal is disregarded, a projection on the train in passing this signal strikes and trips a lever which opens the air-brake line as well as the main circuit breaker, thus cutting off all power and setting the brakes simultaneously.

The diagram on page 95 shows the electrical connections of the track circuits of the electro-pneumatic block-signal system of the Boston Elevated Railway, which was installed by the Union Switch and Signal Company. The description of the operation of the system is as follows:

The branch D from the main feed wire connects directly to two cut-out switches. The right-hand switch controls the current supply to the track circuit, which flows by wire 3 through the two resistance coils, and wire T C to the block rail. These coils have 100 ohms in each, but only on the shortest block sections is the full resistance permissible.

The left-hand switch controls the current to the signal mechanism, which flows normally to the swinging magnets of the polarized relay; from thence it passes to the front contact of the relay, through the contact bar to posts 2 and S, where it divides and flows from 2 to a 16-c. p. lamp, and

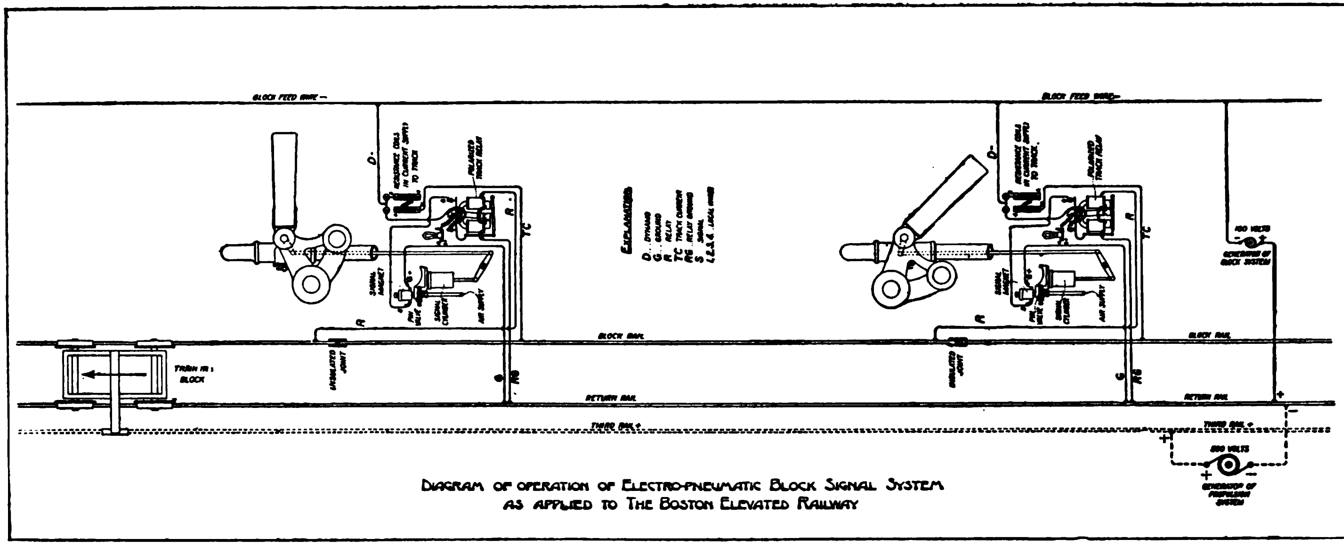


Diagram of operation of Electro-pneumatic Block Signal System as applied to The Boston Elevated Railway

thence to the common return. From S it passes directly to the magnet of the signal air-valve, and from that to the return.

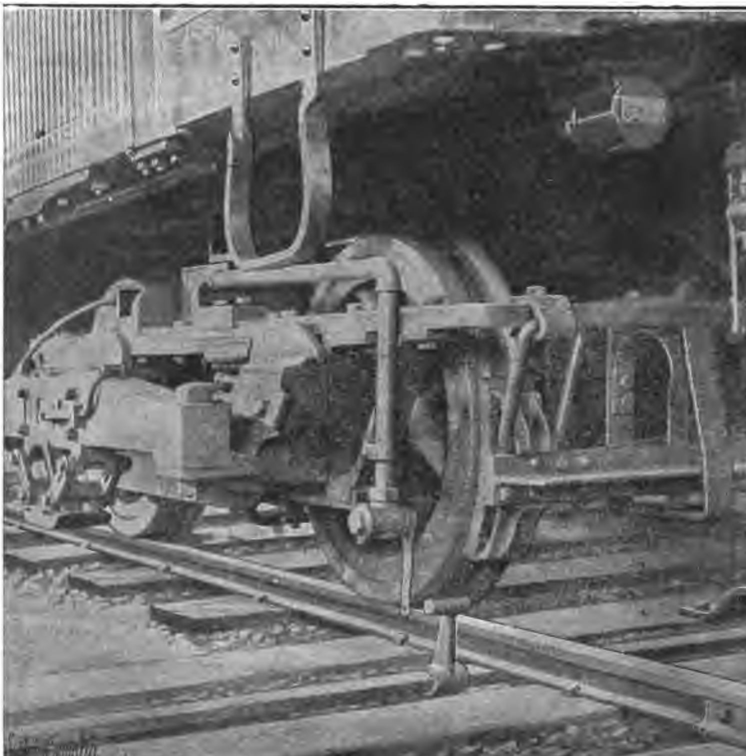
A train short-circuiting the relay causes the front contact to open, thus cutting all current from the signal and lamp and permitting the signal to move by gravity to danger. If, however, the relay should be excited by current from the propulsion system under this condition, the closure of the front contact would not be followed by a similar condition of the rear one (S) because of the polarized feature of the device. The lamp only, under these conditions, remains in circuit with the swinging magnets.

Under normal conditions the signal circuit forms a shunt on the lamp, the coils of the swinging magnets forming a resistance common to both. By this arrangement any interruption of the current through the swinging magnets must also interrupt that holding the signal at safety, and thus cause the latter to move to danger.

The illustration on p. 97 shows one of the automatic trippers used on the Boston Elevated for setting the air-brakes of a train should the motorman attempt to pass the signal while it is in the danger position. This tripper is connected with the signal, and, when the latter goes to danger, is brought in an erect position, as shown in the engraving. It is then high enough to operate a valve in the train pipe carried on the car and thereby cause the air-brakes to be automatically applied and the train brought to a stand still. A system similar to that of the Boston Elevated Railway, which has just been described, is now being designed for the New York Rapid Transit Subway by the Union Switch and Signal Company.

The right of way of any railroad operating over a private right of way should be fenced. This precaution is especially necessary in the case of high-speed roads operating upon private rights of way. A first-class set of right of way fences can be installed for $1,000 per mile. As an investment, this is one of the best which a road can have. The

fences should be substantial and so designed and erected as to make it exceedingly difficult for either persons or animals to obtain access to the right of way between the stations or stopping places. The best fencing is made of wire and can be obtained from any of the large wire manufacturing con-



TRIPPING DEVICE AND AIR-LINE VALVE AND EXTENSION ARM FOR AUTOMATIC STOPPING BLOCK SIGNALS — BOSTON ELEVATED RAILWAY.

cerns. These concerns now make the fencing complete, that is, they have designed and manufactured various types of fencing posts. In addition, these large concerns will take contracts for erecting the fencing for any road at an agreed price of so much per foot of fencing erected.

I have already referred to the increasing use of concrete in railway bridge construction.

The strain sheet (shown in Plate X) is for a 100-foot clear span, concrete-steel arch designed for the New York & Port Chester Railroad. All these strain sheets are worked out by the same method, viz., by the elastic theory of solid elastic arches, which, since the publication of the exhaustive experiments made by the Austrian Society of Engineers and Architects in 1895, has been fully demonstrated to be the correct theory of the arch whatever may be the materials used in its construction. The arches have been carefully designed, the intrados having three centers, and the curve of the neutral line of the arch being such that it is similar to the curve of the equilibrium polygon, so that the bending moment under dead load or under a full dead and live load is very small, and seldom cuts any figure in the maximum section required at any point of the arch. The arch is also calculated under the condition that one-half the span carries the maximum live load, while the other half is unloaded. The table given on the strain sheet gives the maximum thrust and bending moment under different conditions at the governing points. The maximum stress allowed on concrete is 500 pounds per square inch in compression, and 50 pounds per square inch in tension; the maximum stress allowed on steel is 10,000 pounds per square inch in compression and 1,000 pounds per square inch in tension, the stresses on concrete and steel being inversely proportioned to their moduli of elasticity. By careful designing the tension on the concrete has been eliminated, and the compression falls considerably short of the allowed limit. As the allowed tension in the steel cannot under ordinary conditions exceed 1,000 pounds per square inch, there is a very large reserve strength in the steel which can be brought into action if required to satisfy any unusual conditions due to settlement of foundations or other causes, which would not hold true in any purely concrete bridge.

The strength of hand-mixed concrete, 1 part cement, 2 parts sand, and 4 parts broken stone, according to careful and reliable experiments made at Watertown Arsenal, was found to be as follows: 1 month old, 2,400 pounds per square inch; 3 months old, 2,900 pounds per square inch; 6 months old, 3,700 pounds per square inch; and the strength continues to increase up to an age of 2 years or more. At the age of 1 month the concrete would have a minimum factor of safety of from 6 to 8 in the different spans; at the age of 3 months it will have a factor of safety of from 7 to 10; at the age of 6 months it will have a factor of safety of from 9 to 12, and at the age of 1 year it will have a factor of safety of from 12 to 15, and will continue to improve with time.

The factors of safety above given are based on hand-mixed concrete, but in all probability concrete for these bridges, if mixed by a machine, would give much better strength. Experiments of a mixture of 1 cement, 2½ sand, and 5 parts broken stone, which is a poor mixture, from the experiments made at the Munderkingen Bridge in Germany, gave an average strength of 3,730 pounds per square inch in twenty-eight days. Allowing for the difference in mixture, this strength would have been about 4,000 pounds per square inch, or 66 2-3 per cent. stronger than the hand-mixed concrete at Watertown, increasing the factors of safety above given to that extent.

The spandrel walls in all spans are provided with expansion joints at the ends and at frequent intermediate points, to avoid any cracks that might otherwise take place due to settlement on the removal of the centering. More than 100 spans of concrete steel bridges have already been built in the United States, and probably three times this number in Europe, all of which have given the best of satisfaction and are no longer an experiment. They are commended highly by the best engineers in this country and abroad, and are rapidly increasing in number, superseding

steel bridges to a great extent. They offer many advantages over a steel bridge; they are more beautiful and graceful in design; architectural ornamentation can be applied as sparingly or as lavishly as desired; they have vastly greater durability and generally greater ultimate economy; they are comparatively free from vibration and noise; they are proof against tornadoes, high water or fire; the cost of maintenance to the pavements or track is no greater than any other part of the street. Their cost, as a rule, does not much, if any, exceed that of steel bridges carrying a pavement, and in many cases, conditions being favorable, they can be built at a less cost than steel bridges. The steel ribs used in the arches are perfectly protected from oxidation, concrete being the best possible preservative of iron and steel.

In these anchors of 50 feet width (four tracks at 12 feet 6 inches centers) there are 17 steel ribs; that is, the ribs are about 3 feet centers.

CHAPTER X.

OVERHEAD OR THIRD-RAIL CONSTRUCTION.

The next question which will be taken up in the construction of the proposed electric railway is whether to adopt a third rail or an overhead trolley. The latter is the standard for city railways, but the third rail possesses a number of advantages for heavy railway work over the trolley, and is perfectly feasible where the company owns its own right of way. It is, of course, necessary to interrupt the third rail at all grade crossings, which can be passed over by momentum, and also for such track as is laid in streets, or where there is danger of persons coming in accidental contact with the third rail without culpable negligence on their part.

The principal advantages of the third rail over the trolley may be summed up as follows:

1. *Cheapness.*—Taking current carrying capacity into consideration, the third rail can in many cases be installed for less cost than an overhead trolley line, even when we take into consideration the fact that an extra pole line will have to be erected for carrying the high-tension feeders. The cost of third-rail construction and the comparative cost of third-rail and overhead trolley construction is shown by the following:

TABLE VIII.

Cost of Protected Third Rail.

(Estimate made by W. B. Potter; August, 1902.)

6″-Channel Iron Protection.

5,280′	75-lb. 3″ x 2½″ conductor rail, at $43 per ton (66 tons).	$2,840 00
528	Reconstructed granite insulators, clamps and lag screws, at 40 cts. per set	211 00
352	No. 0000 GE 9″ Form B bonds, at 38 cts.....	134 00
		$3,185 00

5,280′	31½-lb. 6″ channel iron guard for conductor rail, at $45 per ton (21.71 tons).	$1,248 00
792	Malleable iron guard rail supports, at 36 cts.	286 00
176	Malleable iron fish-plates and bolts, at 25 cts.	44 00
		$1,578 00
	Approximate labor for installation, including drilling rails and channels	900 00
	Total cost	$5,663 00

8″-Channel Iron Protection.

5,280′	75-lb. 3″ x 2½″ conductor rail, at $43 per ton (66 tons).	$2,840 00
528	Reconstructed granite insulators, clamps and lag screws, at 40 cts. per set	211 00
352	No. 0000 GE 9″ Form B bonds, at 38 cts.	134 00
		$3,185 00
5,280′	48-lb. 8″ channel iron guard for rail, at $45 per ton (42.24 tons)	$1,900 00
792	Malleable iron guard rail supports, at 36 cts.	286 00
176	Malleable iron fish-plates and bolts, at 25 cts.	44 00
		$2,230 00
	Approximate labor for installation, including drilling, rails, and channels	900 00
	Total cost	$6,315 00

8″-Wood Protection.

5,280′	75-lb. 3″ x 2½″ conductor rail, at $43 per ton (66 tons).	$2,840 00
528	Reconstructed granite insulators, clamps and lag screws, at 40 cts. per set	211 00
352	No. 0000 GE 9″ Form B bonds, at 38 cts.	134 00
		$3,185 00

5,280′ Ash plank 1½″ x 8″, at $48 (M board feet) in the rough, 5,280 board feet	$253 00
792 Malleable iron guard rail supports for wooden guard plank, at 39 cts	308 00
176 Malleable iron fish-plates and bolts, at 25 cts	44 00
	$605 00
Approximate labor for installation, including drilling rails	750 00
Total cost	$4,540 00

TABLE IX.

Cost of Protected Third Rail.

(Estimate of Maurice Hoopes; September, 1901.)

Third Rail.

Extra length, 500 ties (9′ 3″ instead of 8′ 0″), at 7½ cts	$37 50
500 insulators and fastenings, at 50 cts	250 00
62.86 tons 80-lb. low carbon rail, at ($35, $2 freight)	2,325 82
Splice-plates and bolts — 176 joints, at 60 cts	105 60
Bonds — 352 425,000 cir. mil bonds in place, at $1	352 00
Cable for crossings — 200′ 1,000,000 cir. mil paper, lead and jute, with terminals and installation, at $1.20	240 00
Erecting rail	100 00
	$3,410 92

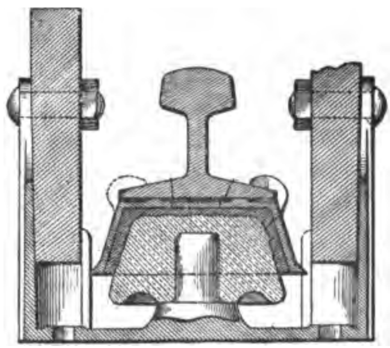
Trolley.

(Span construction and assuming one line of poles chargeable to transmission line.)

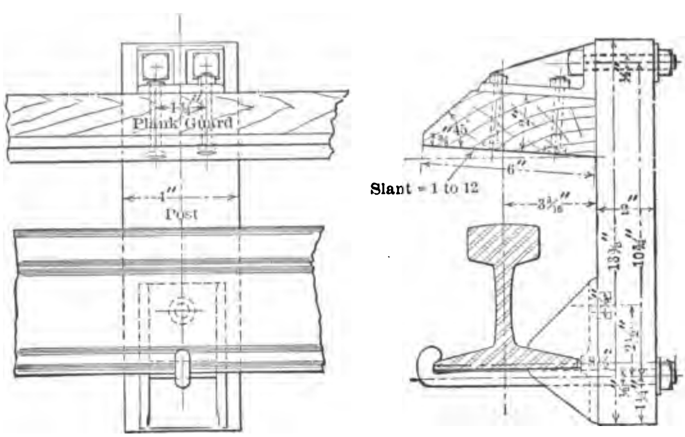
Necessary bare copper trolley and feed wire to give .04025 ohms per mile, thus equaling 80-lb. rail — 1,413,600 cir. mil.= 22,774 lbs., at 17 cts.	$3,871 58
50 30′ x 8″ chestnut poles erected, at $5	250 00
Labor and material for erection of above feeder and trolley wire	300 00
Total cost of trolley construction	$4,421 58
Total cost of third-rail construction	3,410 92
Saving, third rail over trolley	$1,010 66

Or 23 per cent.

In explanation of the foregoing comparative statement it should be said that it is based upon the use of a rail having a resistance of 12.9 microhms per cubic centimeter, giving for an 80-lb. rail .04025 ohms per mile. It also assumes the bonds and cable to have the same resistance per unit of length as does the rail. From the above it will be noted that a mile of third-rail construction costs, approximately, 23 per cent. less than a mile of trolley construction of equivalent conducting capacity.

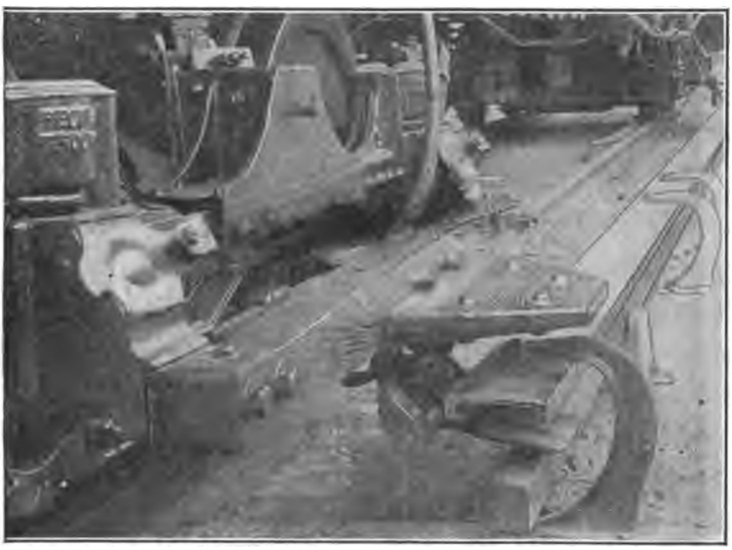


SECTION OF PROTECTED THIRD RAIL AND INSULATOR — BALTIMORE & OHIO RAILROAD.



SECTION OF WOOD PROTECTED THIRD RAIL — WILKESBARRE & HAZLETON RAILWAY.

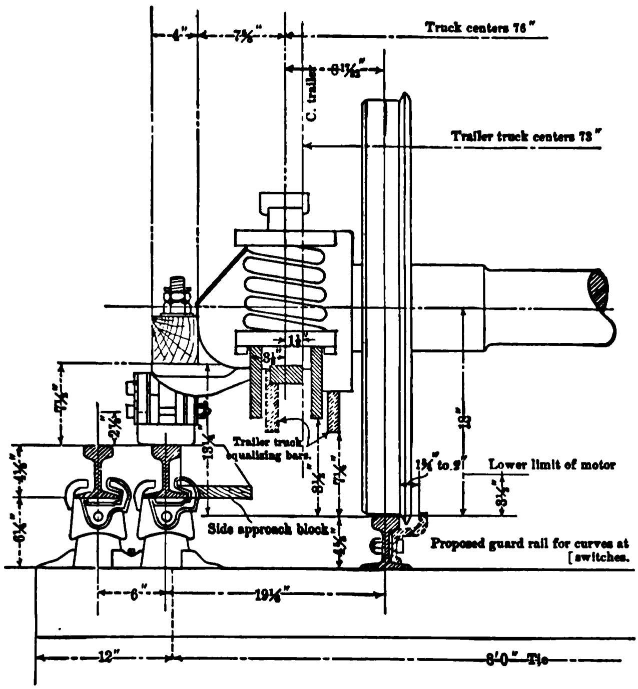
The above statement of comparative cost, by Mr. Hoopes, is probably true of some particular case in hand, but it is very doubtful if the above comparison will hold if it be made general, especially for light traffic, long-headway, cross-country roads. There are very few roads having a resistance per mile equal to an 80-pound rail. Many suburban roads operate with two No. 000 wires and no feeder copper, which is equivalent to a resistance per mile of .1632 ohms, or



CHANNEL IRON PROTECTED THIRD RAIL AND CONTACT SHOE — YARDS OF THE GENERAL ELECTRIC COMPANY, SCHENECTADY.

about four times the amount given as the resistance of the 80-pound rail. If, therefore, 75 per cent. of the cost of copper be taken out, that is, 75 per cent. of $3,871.58, the difference in cost will favor the overhead construction instead of the third rail. For ordinary suburban roads having a very light equipment and operating at speeds not exceeding 40 miles per hour, the overhead trolley is probably, generally speaking, a cheaper construction than the third rail.

2. *Better surface of contact.*— A third rail can be more easily aligned than can an overhead trolley line and presents a practically level surface for the travel of the shoe without



SECTION OF THIRD RAIL CONSTRUCTION — GRAND RAPIDS, GRAND HAVEN & MUSKEGON RAILWAY.

the horizontal and vertical variations unavoidable with the trolley wire. These variations in an overhead line make little difference when a car is running at a low rate of speed, but with high speed there is difficulty in keeping the trolley on the wire, and the effect of the jumping of the trolley wheel is to bend and wear out the wire, both by arcing and mechanical abrasion.

3. *Durability.*— The third rail, being of steel, is practically indestructible, and as the number and area of contact of the shoes can be increased almost indefinitely without trouble, sufficient contact can be insured to carry the enormous current required in high-speed electric-car movement. With the ordinary trolley wheel, from 150 to 200 amperes is about the maximum which can be drawn from the wire at speeds of from 30 to 40 miles an hour, without excessive heating and wear of the wheel. It should be stated, however, that current ranging between 100 to 150 amperes is being drawn from trolley wires at speeds approaching 50 miles per hour on roads in operation in this country to-day. There are several trolley roads which use a current of 200 amperes, and some at speeds of 35 to 40 miles per hour. These roads report an average life of from 3,000 to 5,000 miles per trolley wheel before scrapping takes place. A multiplicity of trolley poles, however, means trouble in their manipulation and excessive wheel wear, while a sliding contact of sufficient area involves wear to the overhead structure and difficulty of securing continuous contact. The cheapness of the ordinary cast-iron shoe, as compared with a copper or bronze trolley wheel, is also a considerable factor.

In view of all these considerations the third rail has been adopted as practically the best standard by high-speed interurban electric lines operating over their own right of way.

The third rail is usually carried outside of the outside rail with its center a distance of about 20 inches from the gauge line of the outside track rail and its top from 6 inches to 7 inches above that of the track rail. The following table is a list of some of the third-rail roads in the United States and Europe, showing the location of the third rail in relation to the track rails:

TABLE X.

List of Third-Rail Electric Systems, Giving Location of Third Rail.

NAME OF RAILWAY.	From Top of Positive Rail to Top of Track Rail, Inches.	From Track Gage-Line to Center of Positive Rail, Inches.
Main line railways.		
Baltimore & Ohio Railroad (old location)........ ...	1¾	24
Baltimore & Ohio Railroad (new location)	3½	30
New York, New Haven & Hartford Railroad.....	1½	Center.
Paris-Orleans Railway, France	7⅞	25⅝
Milan-Gallarate, Italy	7½	26⅝
Mersey Railway, Liverpool	4½	22
Northeastern Railway, Newcastle	....	19¼
Paris-Versailles Railway, France	7⅞	25⅝
Fayet-Chamonix Railway, France	9	23
Wannseebahn, Berlin	12⅝	33½
Interurban railways, electric service only.		
Albany & Hudson Railroad, New York	6	27
Aurora, Elgin & Chicago, Illinois	6 5-16	20⅛
Lackawanna & Wyoming Valley, Pennsylvania. ..	6	20⅜
Grand Rapids, Grand Haven and Muskegon, Mich..	5¾	20⅜
Seattle-Tacoma Electric Railway, Washington.....	7½	20
Elevated and underground electric railways.		
Metropolitan West Side Elevated, Chicago........	6¼	20⅛
Lake Street Elevated, Chicago	6½	20⅛
South Side Elevated Railway, Chicago............	6¾	20⅛
Northwestern Elevated Railway, Chicago	6½	20⅛
Brooklyn Elevated Railway	6	22¼
Kings County Elevated Railway, Brooklyn	5¼	19½
Boston Elevated Railway Company	6	20⅜
Manhattan Railway, New York	7½	20¾
Central London Railway, London	1½	Center.
Liverpool Overhead Railway	1½	Center.
Berlin Elevated, elevated portion	7	......
Berlin Elevated, underground portion	9	......
New York Rapid Transit Subway................	4	26

Where the same track is used for steam trains, it is of course necessary to adjust the height of the third rail so as to clear the cylinder heads or any other projections of the steam train. It is usually supported on every fifth tie, or at distances about 10 feet apart, the ties being of proper length in order to provide support. Where there are breaks in the third rail, approaches must be provided, made either by bending down the end of the third rail and milling off the bottom, or else bending down the end of the third rail slightly

THIRD RAIL TAP AND CABLE TERMINAL — AURORA, ELGIN & CHICAGO RAILWAY.

and clamping to it an end piece of wood or steel of section similar to the third rail itself. It is customary to allow a distance of 8 to 10 feet for the entire length of the approach.

The third-rail insulators are of vitrified clay, reconstructed granite, wood, or composition. The insulator is made in three parts, the iron clamp which holds the rail, the insulator proper, and the stand or chair which is mounted on the

tie. Some engineers believe in fitting these parts loosely together so that the rail is kept in position by gravity only. The argument in favor of this construction is that the weight of the train in passing over the track will depress the ties supporting the third-rail insulators, and it is not advisable to throw the resulting strain on the insulating material connecting the third-rail cap and standard.

The third rail is generally of standard rail cross-section, although any cross-section can be used and the first third-rail roads employed a section similar to an inverted V, but with a flat head. The conducting rail, however, must be low in carbon and manganese, and compared with the track rails is exceedingly soft and would be entirely unfit for use as a track rail. The composition used in the third rail of the Manhattan Elevated Railway Company of New York city, and that recommended by W. B. Potter, in the *Street Railway Journal* for August 2, 1902, are as follows:

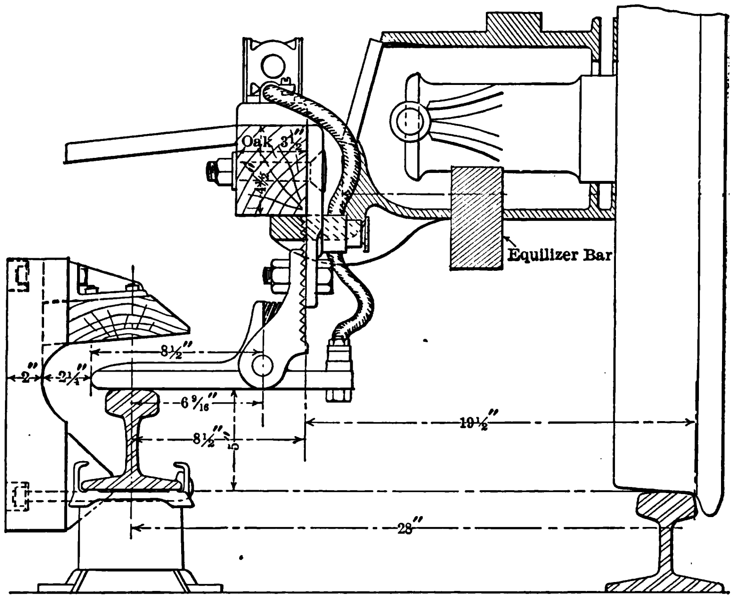
	Manhat'an, per cent.	Potter, per cent.
Carbon, not to exceed	.073	.12
Manganese, not to exceed	.341	.15
Sulphur, not to exceed	.073	.05
Phosphorus, not to exceed	.069	.10

The Manhattan rail is rolled in 60-foot lengths and weighs 100 pounds per yard. It has a cross-sectional area of 9.8 square inches and an electrical resistance of about eight times that of copper of equivalent section, so that in conductivity it is equivalent to about 1,560,000 cir. mils of copper.

As very little strain is brought upon the third rail, two or four-bolt angle plates are usually ample to keep it in alignment. On the Manhattan Elevated Railway, to provide for the expansion of the third rail it is divided into sections of five-rail lengths, or 300 feet each. Each section is securely anchored at the center and allowed to expand from that point. Between the 300-foot sections a gap is allowed for ex-

pansion, depending on the temperature at the time the rail was laid, and an expansion splice bar is used with an allowance for a total variation of about 3 inches.

Opinions differ as to the advisability of housing the third rail, but the latest opinion seems to be in favor of it. It not only protects persons from accidental contact with the rail, but also is a preventive of the interference with the road



SECTION OF PROTECTED THIRD RAIL AND CONTACT SHOE — WILKESBARRE & HAZLETON RAILWAY.

from sleet. This latter is the most serious obstacle with which third-rail roads have to contend and is more troublesome than ice or snow. Ice and snow can be brushed or scraped off, but the thin layer of sleet which forms when the surrounding temperature is just about at the freezing point is so thin that it defies the usual methods of scraping, and clings to the rail somewhat like varnish. On exposed

third-rail roads it is usually removed by means of stiff-wire scraping brushes carried on frames set on the boxes, and it can be loosened by an application of brine. A thin oil spray is also useful in preventing sleet from forming on the rail.

Sufficient experience has not yet been secured with a protected third rail to indicate whether the guard carried over the rail will be an absolute preventive of the formation of sleet, but it certainly reduces the trouble, although it may

SHOE FOR PROTECTED THIRD RAIL OPERATION — WILKESBARRE & HAZLETON RAILWAY.

have a tendency to cause the snow to pack between the head of the rail and the lower part of the protecting plank. The accompanying engravings show the protected third rail as used on the Wilkesbarre & Hazleton railway.

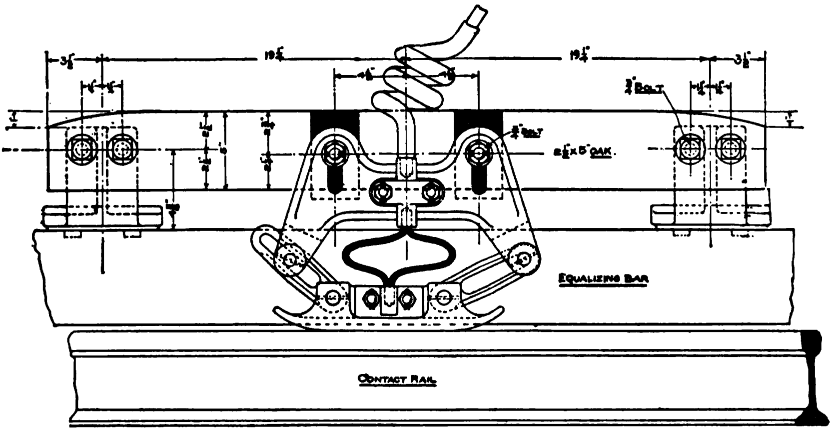
Several other third-rail shoes in use are shown in the accompanying pages. They are all of cast iron and depend upon their weight for contact. The shoes are usually suspended by two links and carry a flexible connection for carrying the current from the shoe to the car wiring, bolted fast to the shoe itself. The permissible range of movement of the shoe depends of course on the height of the head of the third rail above the track rail, and is usually from 3 to 5 inches.

The greater the clearance within certain limits the better, except that the third rail must not be so high that it will be hit by any part of the moving train. Cast iron has been adopted for the material of shoes because copper or brass will not stand the wear from friction. On the Baltimore & Ohio Railroad, where especially heavy current has to be taken, a renewable steel-faced shoe, copper riveted to the body of the shoe support, is used.

SIDE VIEW OF SHOE FOR PROTECTED THIRD RAIL — WILKES-BARRE & HAZLETON RAILWAY.

The end of the shoe is turned up so that it will take smoothly the approaches to the third-rail sections, and for this reason the arrangement of links should be such that the shoe will tilt at positions of this kind. The insulation of the shoe must be exceptionally good as its breaking down would constitute a short circuit through the shoe hanger to the truck frame. Care must also be taken to provide so flexible a lead that the constant vibration to which the shoe is subjected will not tend to crystallize the wire. Usually two leads are used and the shoe hanger should be made adjustable in height to the journal boxes, to which it is usually

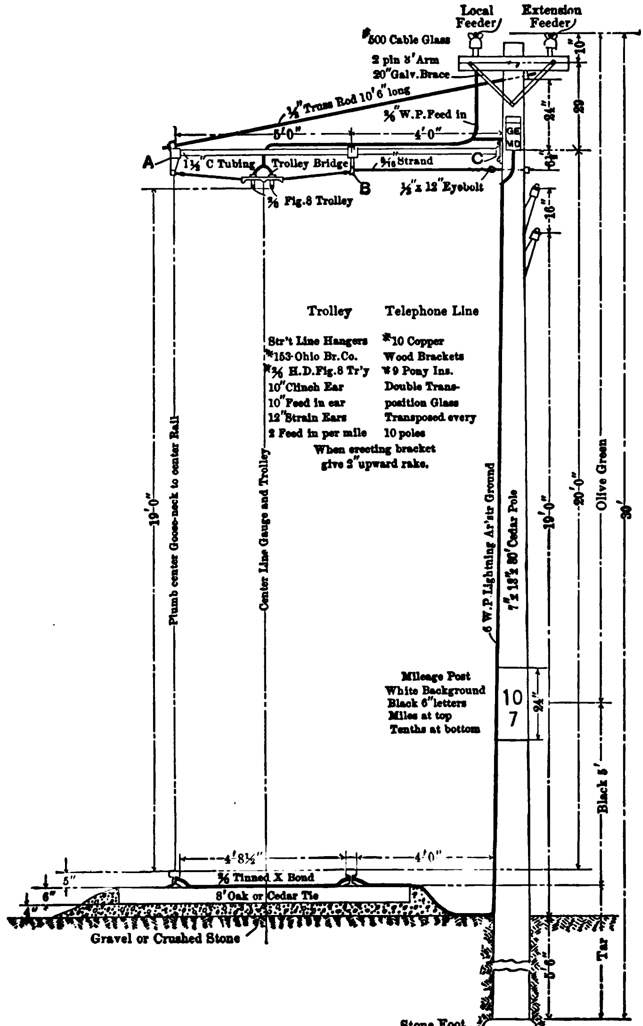
attached, so as to take up any variation in height of the frame or third rail. With a protected third rail the shoe necessarily has to project from the truck so as to extend under the protecting guard, as shown in the cut on p. 111.



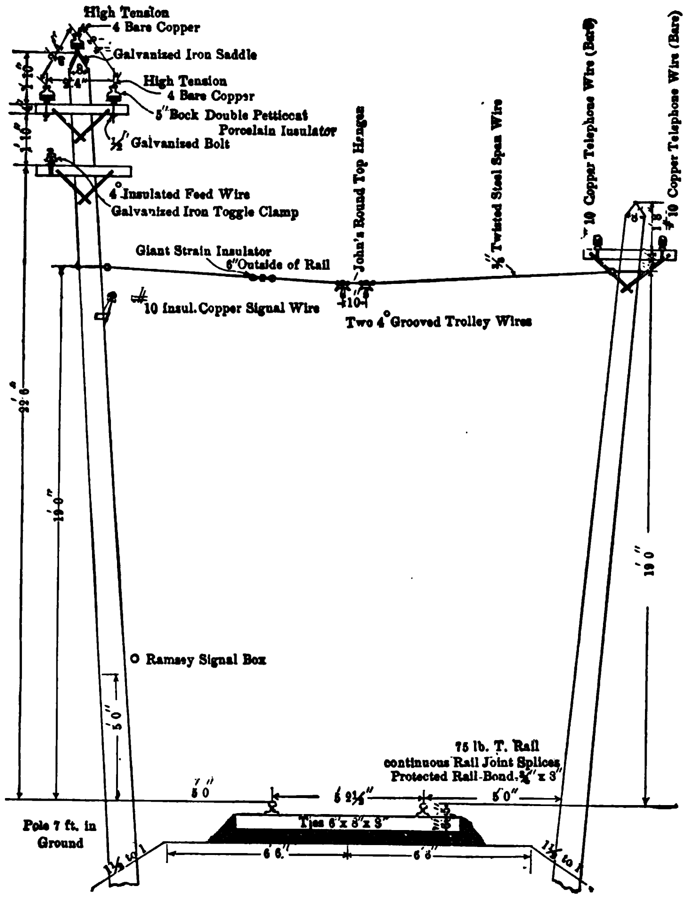
SIDE ELEVATION OF THIRD-RAIL SHOE — MANHATTAN ELEVATED RAILWAY.

Trolley wire construction is so far standardized that it is unnecessary to discuss the subject in detail, but a few points in connection with overhead construction for high-speed roads are worthy of consideration.

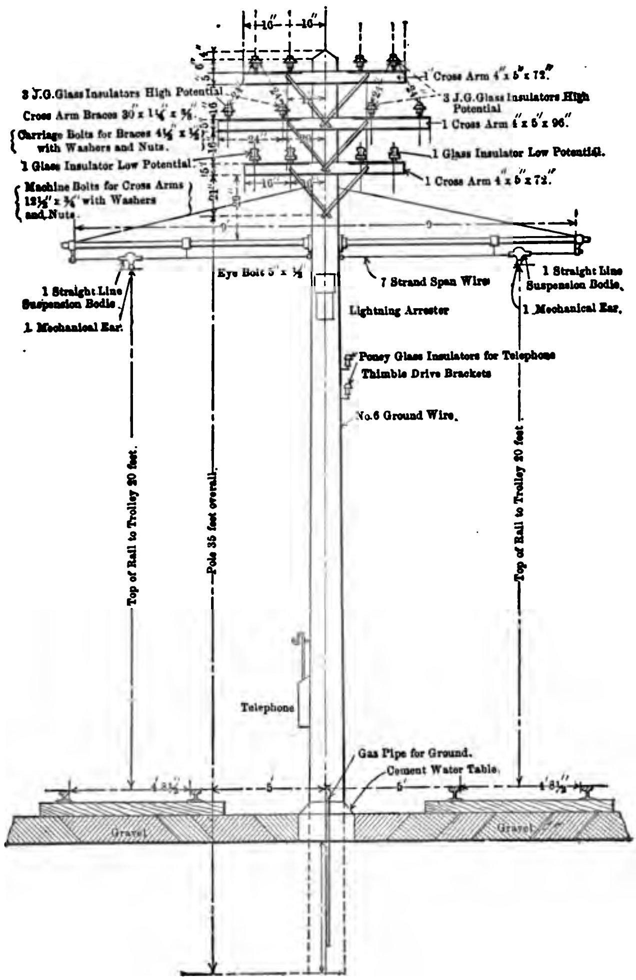
Special care must be taken to insure a good alignment of the trolley wire. Span construction is not generally used on account of first cost, but where brackets are used they should be of the flexible type, as rigid suspension of the hanger to the bracket, inadvisable under all conditions, is absolutely out of the question in high-speed service. The trolley wire should be at least No. 00 in size and should be attached to the hanger by clips which embrace the upper half only of the wire. The wire may be milled out at the sides to receive the mechanical clip of the hanger, if a figure "8" wire is not used. The ends of the ears should be long and tapering to prevent a tendency of the trolley wheel to bend the



STANDARD INTERURBAN OVERHEAD CONSTRUCTION — DETROIT UNITED RAILWAY.



CROSS SECTION OF TRACK AND OVERHEAD CONSTRUCTION — OLEY VALLEY RAILWAY, READING, PA.



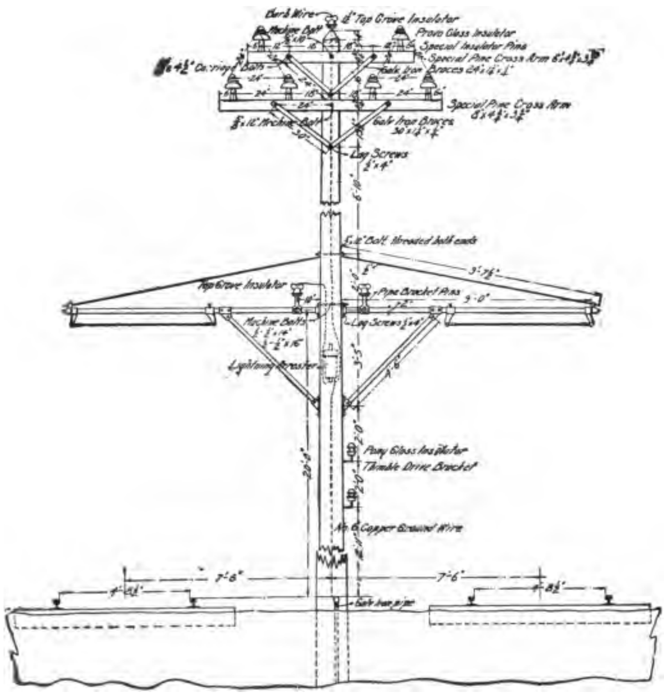
STANDARD OVERHEAD CONSTRUCTION WITH CENTER POLES — BOSTON & WORCESTER RAILWAY.

wire at this point, and overhead frogs should be avoided as far as possible. This is usually done in single-track roads by carrying two trolley wires, one for the cars running in each direction. As the current carrying capacity in each trolley wire is available to supplement the direct-current feeders, no extra expense is involved in the two trolley wires other than that of the additional hangers.

The trolley wheel itself should be not less than 6 inches in diameter, should contain plenty of material and have a groove with a broad base, and the bearings should be especially large and self-oiling. Composite trolley wheels, or those made up with a copper hub and steel side pieces, have been tried for heavy high-speed roads and have been fairly satisfactory, but no system of trolley construction has yet been devised which will satisfactorily care for cars requiring an average of 200 or more amperes and running at maximum speeds of 50 or more miles per hour. For roads having a very light equipment as has already been shown, overhead trolley system can be installed cheaper than the third-rail system. For this class of roads, that is, roads having a very light equipment and a relatively great headway, the limit of overhead trolley construction has certainly not yet been reached. It is entirely probable that in the near future some sort of single phase alternating current motor will be brought out. With such a motor on the market using potentials of 2,000 volts or more, the probability is that for roads having a light equipment the overhead construction will predominate. The matter has, by no means, been thrashed out, although considerable comparative data are now in existence relating thereto. It is unfortunate that there are no reliable comparative data on single phase alternating current motor systems.

On some of the German 3-phase, high-tension, high-speed roads a side overhead contact has been used in which the current collectors are aluminum bars grooved on the edge

and filled with grease, and which are held against the wire by springs, but the construction has not been adopted in this



SECTION OF OVERHEAD LINE AND TRACK — GRAND RAPIDS, HOLLAND & LAKE MICHIGAN RAILWAY.

country, and being especially for the conditions presented on those roads will not be considered in this connection.

In the accompanying pages are shown some standard examples of overhead trolley construction in the United States.

CHAPTER XI.

POWER STATIONS.

The location and proper design of the main power station for an interurban electric railway, or, in fact, for any electric railway, are among the most important factors in the resulting economy of operation, and all points bearing on the subject should be carefully considered before any site for the main power station is finally determined upon. In approaching this subject the first question to be determined is whether an alternating current or a direct current distribution should be used. The determination of this matter will depend upon a number of circumstances, but generally and principally upon the energy which will be required, and the length of the line which will have to be served. The economical limit for direct current distribution, at the ordinary voltages now generally used for direct current distribution, which is from 450 to 550 volts at the motors, is from 8 to 10 miles as a maximum, in cases of what may be termed ordinary power distribution. Assuming, therefore, one direct current power station, located at approximately the center of the line, and assuming the center of the line to be practically the electrical center of gravity of the system, the practical limiting length of line which can be economically supplied with direct current will be from 16 to 20 miles, that is, 8 to 10 miles on each side of the central station. If boosters are used it is possible to increase this length somewhat, but boosters are an uneconomical method of power distribution, and should only be employed under exceptional circumstances and for occasional use, unless the load carried on them is trifling, compared to the total output of the station. In other words, they should only be used in such cases where the total ampere hour output passing through the boosters is small compared with the total ampere hour output of the station.

With alternating current machinery, the limits of economical power transmission are greatly increased, and, as a rule, alternating current distribution will be found more economical for interurban railways exceeding 20 miles in length. It is also generally safe to say that alternating current distribution will be found more economical for lines under 20 miles in length, where the operating conditions demand large energy consumption. Before any system of distribution is determined upon, and before the final plans for the power station or stations are determined upon, careful estimates should be made of the first cost of construction and annual cost of operation, maintenance, and distribution from the single alternating current station and the necessary substations, and also for two or more direct current stations which would be required to do the same work. In making this comparison, the disadvantages of the latter, from an investment standpoint, that is, the extra buildings, greater cost of attendance, and greater reserve capacity (as the reserve will have to be distributed between two or more stations instead of concentrated in one), should be compared with the greater initial cost for machinery for the alternating current system, due to the transformers and other station apparatus, and the various losses through conversion on account of the use of the transformers, etc. In this comparison, as in all railway or other engineering determinations, the possibility of future extensions and developments should always be borne in mind. The power station will be, next to the track, one of the most permanent features of the railway system, and the engineer should, consequently, formulate his plans, not for the immediate conditions, but for those conditions which may properly be expected to develop during the next 20 or 25 years' life of the enterprise.

Should direct current distribution be adopted, the importance of locating the power station near the electrical center of gravity of the system is much more important than if alternating current distribution be used, and this fact may

constitute the determining factor in the selection of the system of distribution, on account of the marked distance limitations of direct current distribution.

Another factor in interurban railway power distribution which should be considered in selecting the type of the power station, and one which, however, does not inherently affect the economical aspect is the advantage possessed by alternating current systems, of maintaining a higher voltage at distant sections of the line, at a relatively low cost. With direct current distribution, a long grade or heavily loaded cars at one end of the line, or both, will seriously affect the speed of the cars, at the point which such grade or loaded car or cars happen to be, and may, and generally will, radically interfere with the schedules of the road, thereby affecting not only the cost of operation, but the earning capacity of the proposed system. This fact should be considered in connection with the selection of the distribution system of an interurban railway system. The inability to secure and maintain speed on distant sections of the line may be, and, in fact, generally is, a far greater disadvantage, than a slight difference in the cost of power distribution.

At this point it may also be well to call attention to another element in favor of the alternating current system of distribution, and that is the possibility, at any time, of the development of a satisfactory single phase or other alternating current motor. Should such a motor, at any time, come upon the market, an alternating current system would have a considerable advantage over a direct current system in adapting itself to the new requirements.

In addition to the matter of economical power distribution there is also that important consideration of economical power generation in the selection of the power station and location. This will depend largely on two circumstances: First, the nearness to a desirable water supply for the feed water and condensing apparatus; and, second, the cost of and

the convenience for the receipt of fuel, such as existing railway or dock facilities. The importance of condensing water lies in the fact that the use of condensers will, in some cases, decrease the cost of power generation anywhere from 15 to 20 per cent., if reciprocating steam engines are used, and to an even greater extent if steam turbines are employed as power generators. It is not intended here to advocate the use of condensing steam engines wherever and whenever condensing water can be obtained. There are numerous cases in existence, where, on account of the location of power stations near coal mines, and on account of the cheapness of coal or other fuel, it can readily be shown that the installation of the high-class condensing steam plants would not be either good engineering or economical, for the reason that the saving which would be effected in the fuel account would be more than offset by the greater aggregate cost represented by the sum of the additional fixed charges and maintenance of the high-class condensing plants. As a general rule, high-class condensing plants should be installed where the cost of fuel is relatively high.

In connection herewith it will not be amiss to call attention to one or two of the small details, such as the arrangements for receiving the fuel. If coal is received by rail, either a spur from a steam railroad should be run into or adjoining the boiler-room, or, if the interurban track is suitable for interchange of cars and the haulage of the coal, these tracks can be connected with the tracks of some existing steam road in the vicinity, and the coal brought by electric power directly to the station. In no case should it be necessary to break bulk and haul fuel by teams, as the cost of labor, incident to the breaking of bulk where such conditions exist, is always practically a fixed charge against the power generation. Other circumstances to be considered in the location of the power station are those of nearness to the car-houses and general offices of the company, and the probable sale of current for lighting and power, and exhaust steam

for heating purposes. The former are advantages often overlooked in power station location. The benefits derived consist principally in the accessibility of the power station force to repair shop tools for making repairs, the feasibility of heating the carhouses and other building with exhaust steam from the power station, and the better supervision of the entire force by the operating manager. The commercial value of the ability to sell current for lighting and power, or exhaust steam for heating purposes, is one which will have to be settled in each individual case. Generally speaking, a location which will admit of this will usually necessitate a power station site well within the limits of a fairly large-sized community, where land is apt to be more expensive, and where the taxes will certainly be higher than out in the country. The determination of this matter will consist in balancing the interest on the increased cost of real estate and other detail charges and costs, such as taxes, construction details, etc., against the probable additional revenue which would be derived therefrom.

Having selected the site of the station, which we will assume, for the present purposes, is a single alternating current station for the entire line, the next question is that of the size of the station.

The proper final determination of the size of station can only be arrived at by a detailed study of electric railway train sheets and run sheets, such as those shown in the diagrams on Plates I, II, and III of this book. The size of station will, of course, vary with the service given, grades, etc. According to tests made on the lines of the Union Traction Company, an account of which is contained in the *Street Railway Journal*, for October 4, 1902, the average power consumption on that line, measured at the car, is given as from 75 to 90 watt hours per ton mile for the local service, and from 58 to 71 watt hours per ton mile for the express service. If the higher figures be taken, and assuming a loss of 30 per cent. between the cars and the high

potential busbars of the station, we will get a consumption of approximately 130 watt hours, and 100 watt hours per ton mile in each case. If the equipment consist of 20 40-ton cars in the local service, making a schedule of 30 miles per hour, and 10 express cars of the same weight for the express service when making a schedule speed of 50 miles per hour, this would give an average demand at the power station of 3,120 kilowatts for the local service, and 2,000 kilowatts for the express service, or a total of 5,120 kilowatts. For this class of service, that is, a service operating relatively infrequent units, a load factor greater than 60 per cent. would probably not be obtained, so that it would be necessary to install in the power station generating apparatus, for a road of this kind, of a capacity of from 8,000 to 10,000 kilowatts, depending upon the extent to which storage batteries are employed to equalize the load throughout the day. The steam equipment would necessarily have to be of a somewhat larger capacity than the electrical apparatus to make up for the engine and turbine loss. If we assume this at 10 per cent. for an 8,000 kilowatt power station, we require about 12,000 horse power in steam engine capacity.

Various methods have been, from time to time, and are yet employed for the purpose of determining the proper location of main power stations, as well as the proper number of and location of the various substations where alternating current transmission is employed. Some of the methods are extremely ingenious and interesting. It may not be amiss to describe very generally and briefly the method followed in determining the location of the main power house and the substations for the New York & Port Chester railroad.

For this railroad the line was laid out, as surveyed, on a sheet of paper to a scale of ½-mile to the inch. As the total length of the main road is about 25 miles, this gave a drawing of about 50 inches in length. On each side of the

center line, representing the surveyed line laid out as above described, were drawn, to scale, the tracks of the road. As the system is designed as a four-track railroad this meant two lines on each side of the center line. At the proper place, and to scale on this diagram, were located the express and local stations, together with the probable location of the storage yards and carbarns. A number of small pieces of cardboard were then cut out to represent the train units of the system. Various energy determinations, relating to different conditions of operation of the system, were then made as follows:

First. A determination was made as to the amount and distribution of the load which would occur during the times of maximum service. To do this reference was had to the graphical schedules or train sheets, and especially to the one representing the total train movement (see p. 40). From these train sheets data was obtained which enabled the placing of the small strips of cardboard, representing the train units, at their proper places upon the express and local tracks as drawn. From the train sheets information was also at once obtained as to the operating condition of each and every train unit. By reference then to the proper run sheet, the energy consumption of each train unit, as located on the diagram of the road as above described, was at once ascertained. That is, the train sheet, in conjunction with the run sheet, enable us to indicate, at the position of each car or train unit, as shown on the diagram, the exact location and amount of energy consumption of that car or train unit, which, of course, would vary depending upon the position of the unit upon the road, that is, whether it was at a station, starting out from a station, or running between two stations, as well as whether the unit consisted of one car or three or more cars. The energy consumption of each unit was then written along side of that unit, after which the electrical center of gravity for the system, with the given loading, was determined. The process followed in this determination is like that which would, ordinarily, be followed

in ascertaining any mechanical center of gravity for a system of distributed loads. Ten or more of these determinations were made and the electrical center of gravity for each determination, representing collectively the different conditions of light, average, and maximum loads, ascertained and noted on the sheet. It should be borne in mind here that it may be very improper to assume for the proper location of the main power-house a point, obtained by taking the conditions and making the determinations during the hours of maximum service, in such cases where the average load, throughout the day, is fairly heavy and uniform, and the maximum load maintained but a relatively short time throughout the 24 hours, and where the electrical center of gravity obtained by considering the average load differed considerably from that obtained by reference to the maximum load alone.

After various points representing the electrical center of gravity, for different conditions of loading of the system of the New York & Port Chester Railroad Company lines had been determined, a point was finally settled upon by considering three or four points representing average maximum conditions. This process is again similar to that of obtaining the mechanical center of gravity of any system, by considering a system of weights distributed at a number of points, and thus obtaining the mechanical center of gravity for the system of weights. The point so determined upon for the New York & Port Chester Railroad Company gave a main power-house location well within the limits of a city where real estate was relatively high, and where it would not be possible easily and cheaply to obtain the water requisite for the condensing prime movers. After further investigation a point was selected at a distance approximately a mile away from the center above referred to. It then remained to determine the relative cost, all factors considered, of operating and maintaining these two stations. For the point determined upon as the theoretical point well within the limits of a large population center it would have been

necessary to expend considerable money in bringing water to the power-house. Arrangements would also have to have been made to get the fuel to the power-house. It was also at once apparent that on account of the size of this main station, which would require about 20,000 horse power of boilers, the boilers would have to be placed in tiers. The interest on the cost of the station located at the point theoretically determined upon was then ascertained, together with the additional cost of bringing the water to the station, as well as the cost of making proper arrangements to receive the fuel. On the other hand, the cost of locating the station on a water front, the alternate plan under consideration, with the cost of providing proper docking facilities for the fuel, the cost of the additional length of the transmission lines, and the annual cost of transmitting the required energy over the additional distance were ascertained, and the sum total of these costs was compared with the sum total of the costs obtained for the theoretically proper point. The results showed a balance in favor of the station located on the water front. I regret that commercial and other considerations are such at the present time that I cannot publicly indicate the location of these two points, and thereby better illustrate the determinations. I think, however, the process above described will illustrate a methodical way of approaching and solving problems connected with the location of central power stations.

The roadway having already been divided up into sections, the matter of the location of the substations was approached in the same manner, by obtaining the most advantageous point after considering different conditions of loading of the sections which would occur at different hours of the day. We finally determined upon three substations.

Before all this had been done computations had been made upon the first cost and the cost of maintenance and transmission of two large direct current stations. The computations indicated, at a very early stage of their progress,

that recourse would have to be had to the alternating current system of transmission. The determinations to use the alternating current system was further influenced by the conviction that the day of the commercial alternating current motor is not far off, as well as by the fact that other systems with which the company will probably have business relations were compelled to use the alternating current system of transmission.

The load diagram for each of the substations as well as for the main station should be prepared by having recourse to the train sheets above referred to, and the run sheets. Another blank sheet, similar to that used for the train sheets, or the run sheets, is taken, and the energy consumption of each run projected on this new sheet to scale. That is, if the length of the run as represented on the train sheet between termini is 2 inches, then the energy consumption for each run reduced to that scale is projected on to this new sheet. Each of the individual runs are superimposed upon the one preceding it, or graphically added to it, and each commenced at its proper place on the sheet. This process will give a scientifically accurate load diagram, from which the details of the substations and main power station, such as size and number of units and size of storage batteries, if their use be determined upon, are ascertained.

The question of the size and number of units for any given total capacity of station is an interesting one, and one which must be determined in each individual case. An inspection of a number of power stations, now in operation, would indicate that, at the present time, a division of units approximately, as follows, is being used:

Kw. Required.	Units in Use.	Units in Reserve.
1,000	2 — 500	1 — 500
2,000	3 — 800	1 — 500
3,000	4 — 800	1 — 800
5,000	1 — 800 3 — 1500	1 — 1500
7,000	2 — 3500	1 — 3500
10,000	3 — 3500	1 — 3500

For purposes of information, I have appended herewith a table showing the results of the investigations of Dr. Chas. E. Emery, and giving the comparative cost of producing power by the use of different types of reciprocating steam engines. This table is of value and interest. Personally, I believe, it will very soon be superseded by the data which will be produced on account of the use of steam turbines.

It is not the writer's intention to discuss in detail the proper design of an electric railway power plant; but a few suggestions on the main features of the plant may be considered in this connection.

The building should be of fire-proof construction. It is usually of brick, with steel trusses, and with wooden roof, covered with tar and gravel, and provision should always be made for a traveling crane spanning the engine-room, for use not only in installing engines and generators, but for convenience in lifting heavy parts so as to get at the machinery in case repairs are necessary. Plenty of room should be provided around the different units for ease and safety in inspection, and to permit the removal of piston rods, if necessary, without lifting the cylinder from its foundations. It is also advisable to so design the building that extensions to it can easily be made without interfering with the general scheme of the plant.

Where real estate is valuable, the boilers are sometimes located over the engines, but in most interurban power plants it will be found entirely practicable to install them in an adjoining bay, separated from the engine-room by a brick wall. As the engines must necessarily be at a higher level than the condensers, if condensers are used, so as to prevent the water of condensation setting back into the cylinders, the engine floor is usually elevated 8 or 10 feet above the ground level in preference to installing condensers in a pit. The construction, however, depends upon the height of the condensers above the level of the water to be used for condensing purposes.

TABLE XI.

Showing Comparative Cost of Power in Engines.

TYPE OF ENGINE.	Feed Water per 1 H. P. per Hour.	Cost of Engines Erected per H. P.	Cost of Engine, Boilers, Building and Stack per H. P.	Coal per H. P. Hour in lbs.	On Basis of 365 Days of 20 Hours Each per Net H. P.: Cost of Coal at Price per Ton of 2240 lbs. Given Below.		On Basis of 365 Days of 20 Hours Each per Net H. P.: Total Operating and Interest Expenses Except Coal.	Total Cost per Net H. P. for Electric Railway Service Including Reserve (See Note Below) on Same Basis as Before, Coal per Ton at	
					$3.00	$5.00		$3.00	$5.00
Simple high speed, noncondensing	33	$17.50	$58.90	3.882	$43.20	$72.00	$27.69	$76.54	$105.34
Simple low speed, noncondensing	29	25.00	62.85	3.412	38.95	64.92	26.60	71.64	97.60
Compound high speed, noncondensing	26	21.00	54.81	3.059	34.04	56.74	25.57	64.87	87.57
Special triple compound high speed, noncondensing	24	26.00	60.25	2.824	31.42	52.37	26.01	63.32	84.27
Simple high speed, condensing	22	21.00	50.42	2.588	28.80	48.00	24.02	57.65	76.85
Simple low speed, condensing	20	27.00	54.85	2.353	26.86	44.47	23.39	55.55	73.46
Compound high speed, condensing	20	24.50	51.74	2.353	26.18	43.64	23.81	54.96	72.42
Compound low speed, condensing	18	30.00	55.62	2.118	24.18	40.30	23.09	52.66	68.78
Special triple compound high speed, condensing	17	29.00	54.84	2.000	22.26	37.10	23.67	51.28	66.12
Triple compound low speed, condensing	16	37.50	62.67	1.882	21.48	35.81	23.77	51.42	65.75
Do. for probable maximum results	14	45.00	66.10	1.474	16.83	28.04	25.34	48.79	60.00

NOTE.—The final column includes the following items which should be added in electric railway service—interest, etc., on 50 per cent. additional plant required as reserve to obtain the average of 500 H. P., insurance increased to 1⅛ per cent., engine renewals to 4 per cent., and boiler renewals to 5 per cent.

Commencing, first, with the steam generating part of the equipment, boilers can be broadly divided into two classes, fire-tube and water-tube boilers. As far as safety is concerned, the water-tube boiler is, of course, superior to the fire-tube type; they are also quicker in steaming (an important advantage where fluctuating loads such as are encountered in railway work are concerned), and they are much preferable when the pressures are as high as 150 pounds. Fire-tube boilers, particularly return tubular boilers, are less expensive in first cost; and when internally fired are probably as economical as water-tube boilers, if not more so; but for the reasons already mentioned, water-tube boilers are used almost exclusively. In all cases the boilers and their furnaces should be designed to suit the kind of coal to be employed, as some coals require more grate surface than others. As all boilers have to be cleaned, and as they have to be cleaned frequently when scale-producing feed-water is used, it is always desirable to have 1 or 2 batteries of boilers in excess of those actually needed for operating the plant.

The type of engine to be adopted depends mainly upon two factors, the size of the unit and the cost of fuel. The latter consideration affects the choice, from the fact that it would be manifestly absurd to purchase an expensive and highly efficient engine for a plant where fuel is very cheap.

Where an engine is used only occasionally, as in case of a booster engine, or one to carry the peak of the load, it is not necessary to have so efficient, and hence so costly a machine as where the engine is intended for continuous running. In all electric railway work it is desirable to have an engine which can take fairly easily an overload, without great loss of economy, and also an engine which will regulate closely in speed. The speed regulation is usually specified to be within 2 per cent. between full load and no load.

The piping should be designed, so that if any condensation occurs the water will flow in the direction in which the steam is moving, and will then be caught in traps or separators be-

fore it can enter the cylinders. Stations are often provided with a duplicate set of piping so that if any portion of the piping gets out of order it will not involve a shutting down of part of the station. This plan does not necessarily involve parallel lines of main and branch piping, as the boiler and engine piping can be arranged on a ring or loop system so that the steam can flow in either one direction or another as required. Some of the latest power stations, however, are not arranged on this plan, but are fitted with what is known as the "individual-unit" system, by which a certain set of boilers is normally used only for generating steam for a certain engine, but by cross-connections in the boiler-room, steam from other batteries of boilers can be utilized for this engine, if desired.

The condensers may be either of the jet, surface, or siphon type. The two former require an air pump, and the jet condenser is the one most generally used. It requires a much smaller surface than the surface condenser, and is much less costly. The only advantage which the surface condenser possesses over the jet condenser is that as the condensed steam does not come into contact with the circulating water, the steam when condensed can be used again in the boilers. The difficulties in the way of the removal of the cylinder oil from the discharged steam, either before or after it is condensed, are so great, however, that surface condensers are not generally employed in power stations. But with the introduction of steam turbines where no lubrication is required in the steam chambers, surface condensers will undoubtedly come into more general favor. In the siphon condensers the steam is led to a point about 34 feet above the surface of the water in the hot well, and is there mingled with the circulating water and condensed, producing a vacuum.

Feed-water heaters are used to heat the water fed to the boilers, and utilize for this purpose the exhaust steam from the engine or auxiliaries before it is led to the condenser. They form a necessary part of the economical equipment of

a power station. In some cases two sets of feed-water heaters are used — primary heaters for utilizing steam from the engines, and the secondary, steam from the pumps. From the heaters the feed water is often led to economizers, which consist of nests of tubes surrounding the flues at the base of the stack.

Draft is provided either by a chimney or mechanically by fans. Mechanical draft possesses many advantages over natural draft, of which the most important is that the draft can be regulated according to the needs of the furnaces. In some stations natural draft is depended upon for all times, except to care for the peak of the load, when the capacity of the stacks is increased by running the fans.

The cost of the main power station will vary from $78 to $133 per rated kilowatt capacity of the station, divided as follows:

TABLE XII.

Reciprocating Steam Engine Power-Station Costs Per Kilowatt.

No.	Item.	Maximum.	Minimum.
1.	Buildings	$15 00	$8 00
2.	Foundations	3 50	1 50
3.	Boilers and settings	17 00	9 00
4.	Steam piping and covering, etc.	12 00	4 00
5.	Engines	32 00	20 00
6.	Generators	21 00	18 00
7.	Pumps, etc.	1 00	1 00
8.	Switchboards, etc.	4 00	1 50
9.	Feed-water heaters, etc.	2 00	1 00
10.	Wiring conduits, wiring, etc.	6 00	3 00
11.	Coal conveyors, and coal storage tanks	6 00	2 00
12.	Smoke-stack and flues	2 00	1 00
13.	Fuel economizers	4 50	2 50
14.	Stokers	3 00	2 50
15.	Ash conveyors	1 50	1 00
16.	Incidentals, such as concrete flooring, etc.	2 00	2 00
		$132 50	$78 00

A fair average cost for kilowatt will be between $100 and $110.

The cost of an installation, using steam turbines as prime movers, at the present time is about 70 per cent. of the maximum costs above given and probably will be much less than this within a few years. The manifold advantages of a turbine installation are too apparent to require much explanation. In the order of their importance they may be summed up as follows:

1. Simplicity.
2. Marked economy in fuel consumption over the reciprocating steam engine.
3. Lower cost of operation and maintenance.
4. Less floor space and consequently less real estate required.
5. Lower initial cost.
6. High efficiency over a wide range of loads.

The cost of substations using rotary converters will vary from $45 per kilowatt as a maximum to $38 per kilowatt as a minimum, including the building and wiring, etc.

The cost of the electrical conducting circuits will vary between $1,000 per mile of track for light traffic roads and $3,500 per mile of track for fairly heavy service. This is based upon a high voltage alternating current main station with high voltage transmission to the substations, and about 600 volts at the rail.

The cost of the passenger stations will depend entirely upon the disposition of the railroad company and may be anywhere from $1,500 to $20,000 per station.

The diagrams on Plates VII, VIII, and IX show wiring details of several stations in actual existence. There is shown the wiring diagram of a main alternating high-tension generating station, together with the wiring diagram of a substation receiving alternating current at high potential and transforming such alternating current by means of rotary converters to low tension direct current, after which it is sent out to the trolley wire or third rail, as herein described.

CHAPTER XII.

STORAGE BATTERIES.

Storage batteries have, during the last few years, been used to an increasing extent in the equipment of electric generating stations and substations, more especially in cases where the electric load is subject to fluctuations and variations.

A comprehensive discussion and complete analysis of the considerations which enter into the determination of the size of battery installed, and the details of its operation, etc., would require more space than can be devoted here to these points. Many interesting and valuable articles, by specialists in storage battery engineering, have been made public at different times in technical periodicals and publications. The battery manufacturers, especially the Electric Storage Battery Company, have also compiled and issued much valuable information on this subject.

I shall confine myself to a summary indication of the principal applications and uses of storage batteries.

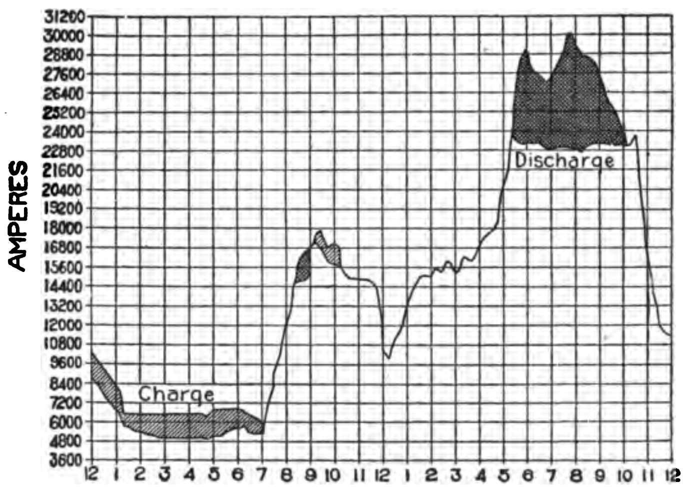
The advantages of storage batteries depend, primarily, upon the fact that they enable the energy to be expended at a different time from the time at which the said energy is generated; moreover, owing to the fact that they render the time of the output independent of the time of the production of energy, they incidentally render the rate of the output independent of the rate of the production, since they can supplement either the *generators* or the *load.*

The utility of the storage battery in a specific case may hinge on either or both of two things: First, its total capacity as a reservoir of energy; second, the maximum rate of charge and discharge which it can withstand.

In some cases it is the first of these qualities that is most essential and useful; in other cases it is the second only, while there are cases in which both qualities are desirable.

These points can be easily and clearly shown by means of the accompanying load diagrams, for which I am indebted to the Electric Storage Battery Company.

In the engraving on this page, the irregular line represents a load diagram, such as is characteristic of an ordinary central electric generating station. It is well known that in such stations the load falls down to its lowest point in the early



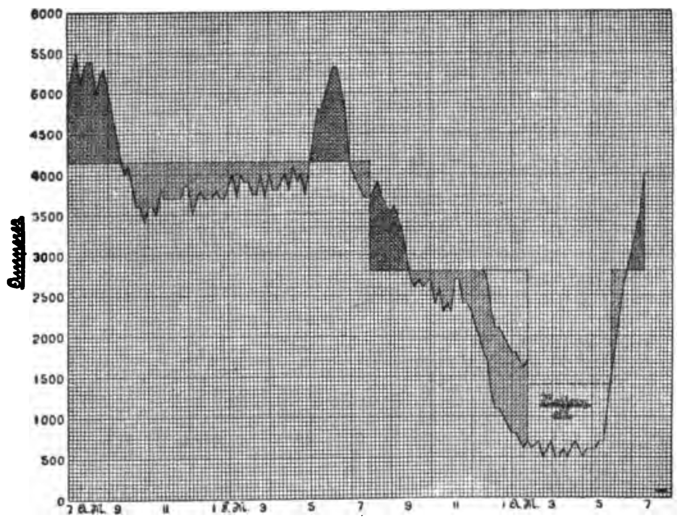
LIGHTING BATTERY CARRYING PEAK ON EDISON THREE-WIRE SYSTEM.

morning hours, and that the heaviest load occurs in the afternoon and early evening hours. In such cases a storage battery fulfills an important function, by enabling the load on the plant to be increased during the early morning hours. The shaded area in that portion of the diagram, representing the time interval between midnight and 7 A. M., represents the amount of energy that is expended in charging the batteries during that period.

In the particular case represented, the battery was allowed to discharge so as to supplement the generating plant,

when the load increased between 8 and 9 A. M., but it was again charged for a short time between 9 and 10 A. M. At the time of the heavy load, namely, between 5 and 10 P. M., the battery was made to discharge, so as to take care of the "peak" of the load, as clearly indicated by the heavily-shaded area in the diagram.

In the diagram below we have a similar condition, illustrating the use of a storage battery at a railway power-house,



BATTERY AT RAILWAY POWER-HOUSE TAKING LOAD. POWER DERIVED PARTLY FROM STEAM UNITS, PARTLY FROM WATER POWER THROUGH ROTARIES.

for the purpose of taking care of the larger "peaks" of the load, and also of equalizing the smaller and more frequent changes of the load, represented by the smaller "peaks" or waves in the diagram. It will be seen that in this case the load on the generating plant, between 7 A. M. and 7: 30 P. M., was maintained uniformly at 4,150 amperes. As the actual load between 7 A. M. and 9: 15 A. M. was much higher than 4,150 amperes, being most of this time above 5,000 amperes, the

battery was allowed to discharge during that time so as to "peak" the load, as indicated by the heavily-shaded area in the corresponding portion of the diagram. About 9 : 15 A. M. the load had decreased to a point where it became less than 4,150 amperes, and it continued below 4,150 amperes until 5 P. M. During this period the battery was allowed to charge, the energy stored in the battery being indicated by the lightly-shaded area in that portion of the diagram. Between 5 and 6 : 40 P. M. the battery was again allowed to discharge, so as to "peak" the load, which reached a maximum of 5,300 amperes. Between 6 : 40 and 7 : 30 P. M. the battery was again allowed to charge. At 7 : 30 the generating capacity was reduced to 2,800 amperes, the storage battery being allowed to discharge so as to take care of the excess of the load above 2,800 amperes. Shortly after 9 P. M. the load fell below 2,800 amperes, and the battery was again allowed to charge. The load was maintained constant at 2,800 amperes until midnight, at which time the total load was allowed to decrease, this being done to prevent charging the battery at an excessive rate. At 1 A. M., the battery being fully charged, it was cut out, and the generating plant was run at a lower output, ranging between 500 and 700 amperes. The battery was again put on for charging at 5 : 30 A. M., so as to give a total load of 2,800 amperes on the generating plant, this load being maintained constant until about 7 A. M., notwithstanding the rise in the external load; the difference between the power generated and that required for the load being made up by allowing the battery to discharge so as to carry the "peak," as indicated by the heavily-shaded area of the corresponding portion of the diagram.

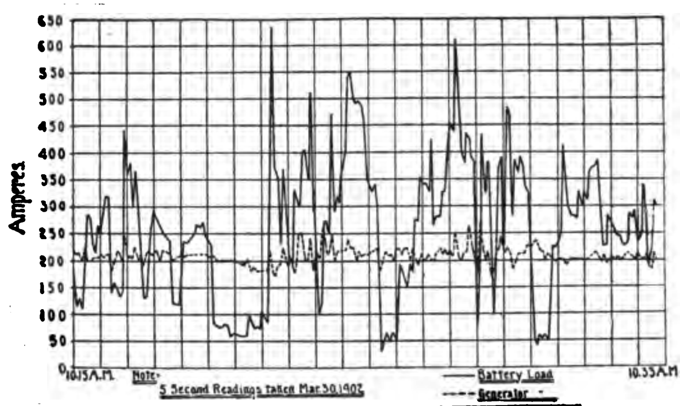
The load curves thus far considered show changes of load which lasted a considerable portion of time; the larger "peak" in the first diagram lasted over five hours, and the two larger "peaks" in the second lasted each one hour or more. In each case the shaded portion, representing charge

or discharge, according to the case, is a measure of the total amount of energy which was charged into, or discharged out of, the battery. The height of the shaded portion at its highest point represents the maximum *rate* at which the energy was charged or discharged. It is found in practice that the proportion of the "peak" for which the battery can furnish the current in discharging depends upon the maximum rate of discharge which the battery is able to withstand. This maximum rate, itself, in turn depends upon the length of time during which the discharge is required.

This brings us to the consideration of changes of load of another kind, namely, the very sudden and severe, but brief, instantaneous changes of load, which are usually designated by the term "fluctuations." These fluctuations, as is well known, are due to the sudden starting and stopping of cars, and the consequent variations in the current required by the different cars. It is found that the number of these fluctuations *increases* while their severity *decreases* with the number of cars. This means that the range or extreme limit attained by the fluctuations varies in some inverse proportion with the number of cars in operation. In the case of a small line, the fluctuations are very marked. There may be times when the generators are running practically without load for a few seconds, while a few seconds later they may be greatly overloaded. In order to appreciate these variations in the load, the load line would have to be plotted according to a larger scale of time values.

In the cut on p. 141, the solid line shows the load diagram obtained at an electric substation furnishing current for an electric railroad system. In this case the readings were taken every five seconds, and the diagram reproduces the corresponding values. The dotted line represents the load imposed upon the generators, the current being, in this case, generated by rotary converters. It would seem that while the mean load, as indicated by the dotted line, was a trifle over 200 amperes, the actual line-load fluctuated between 60 and

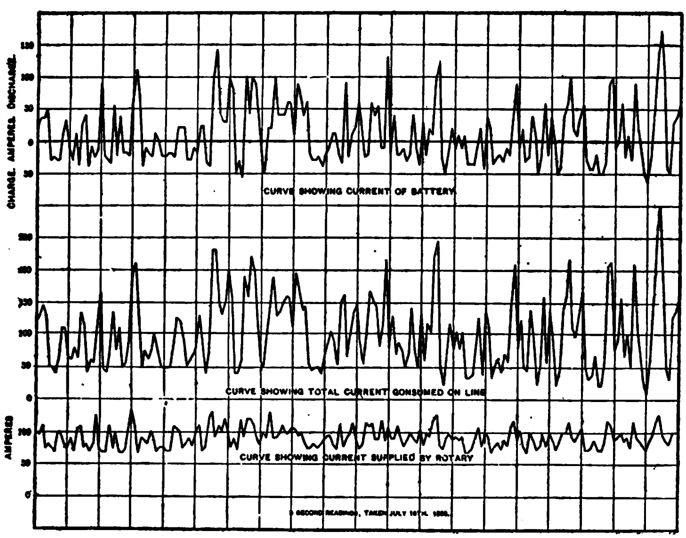
630 amperes. It will be noticed that the most severe fluctuations are of very brief duration. In such a case, the rate of charge and discharge that would be allowable in the battery would be very much greater than would be allowable if the fluctuation, instead of lasting a few seconds, were to extend through several minutes, or were to constitute a "peak" as large and lasting as long as those shown in the two previous diagrams. In cases such as those just referred to, a large storage capacity is of very great importance,



RAILWAY BATTERY AT ROTARY SUBSTATION TAKING FLUCTUATIONS.

because the amount of energy stored and the length of time during which it is to remain stored are both large, whereas in cases where the fluctuations are brief and numerous, even though they are severe, the storage capacity required is relatively small and the battery serves, merely, so to speak, as a means of transferring a portion of the load from one instant of time to another instant of time relatively close to it. At one moment it gives out energy to supplement the generators and to "peak" a certain fluctuation, due to a sudden rise in the line current, while at the next moment it may absorb current, owing to the fact that the load on the

line has suddenly fallen below the average generator load. A battery working under those conditions is said to serve as a regulator or equalizer. It has also been said to be equivalent to an electrical "ballast" or electrical "flywheel." The term "buffer-batteries" has also been used in Europe to designate batteries which are used as regulators or equalizers in this manner.



CURVES SHOWING REGULATING EFFECT OF STORAGE BATTERIES.

The regulating effect of the battery will be more clearly understood by reference to the diagram on this page, in which are shown separately, first, the curve (middle line) showing the total current consumed on the electric line; second, the current curve of the battery, drawn with respect to the line of zero current, the portions above said line being charges and the portions below said line being discharges of current; third, the curve (lowest line) showing the current sup-

plied by the rotary converter. It is seen that the battery curve follows very closely the load curve. The generator curve clearly indicates that the fluctuations of load have but little effect upon the generator load, which, in this case, does not vary more than 25 amperes above or below the mean load, notwithstanding the fact that the fluctuations represent a range of nearly 300 amperes between the extremes of fluctuation.

Economy in cost of producing electric power requires that attention be given to two important points. First, that the machinery should work as many hours and as fully loaded as possible; second, that it should work as efficiently as possible.

The first point is related to the initial outlay required for the generating plant, it being readily apparent that if a given total output in hp or kw hours can be produced by a smaller plant, the initial investment will be less than if a larger plant were to be used. Referring again to the cut on p. 137, it can be seen that if it were not for the battery the generating plant would have to be of sufficient capacity to carry 30,000 amperes, merely because the load reaches that limit for a short period of time amounting to less than one hour during each twenty-four hours. On the other hand, with the use of a storage battery capable of furnishing current for a "peak" of the load, the maximum generating capacity required, as shown by the diagram, would not exceed 24,000 amperes.

In a case, such as shown in the cut on p. 137, the battery itself, of course, represents a certain initial outlay, which, if the battery had not been installed, could have been expended for additional generators; consequently the advantage of the storage battery would be doubtful if it served no other useful purpose than that of "peaking" the load. This is more especially the case since, in all probability, the battery for carrying a load "peak," such as shown in the first diagram, would cost more than the generating capacity re-

quisite for carrying the same "peak." The battery, however, subserves additional purposes. This brings to our attention the second point, namely, the importance of operating the plant at maximum efficiency. It is well known that there is, for each generating unit, a certain definite load, at which the said unit operates the most efficiently, the total cost of power per unit being higher per hp or per kw when the load is made either greater or less than this definite load. In the case of fluctuating loads the falling off in efficiency is very considerable. It is especially in such cases that the storage battery has been found capable of rendering good and effective service. In a case, such as is shown in the second diagram (p. 138), where the introduction of storage batteries enables the load to be maintained at a substantially uniform point during the greater portion of the working day, it becomes possible to operate the generating units in such manner as to obtain a relatively higher efficiency than would be the case without the battery. The result of this improved efficiency would be manifested in the reduction of fuel, supplies, and other items entering into the cost of power.

Since there is a certain percentage of the energy generated that is lost in the storage battery itself, however, it is evident that the total benefit from the improvement of the generator efficiency is not obtained by the use of a storage battery. Making allowance, however, for the energy lost in the battery and for the extra amount of energy that would have to be generated for a given electric train service, in consequence of this loss, it may happen, and it frequently does happen, that the total cost of the power required for a given service is still lower than would be the case without the battery.

From the standpoint of maximum economy and of lowest cost of electric current production, the important question is whether the savings effected by the use of a storage battery are greater than the losses incidental to its use. As

a matter of fact there would be no economic advantage resulting from the use of a storage battery if the total cost per unit of current generated, including all fixed charges and operating expenses, were not brought down to a lower figure with a storage battery than without it, so as to represent a certain margin of profit or saving.

The considerations which I have just outlined constitute the criteria by means of which the applicability of storage batteries to different cases is gauged, and by means of which the size or importance of a storage battery equipment in these cases is determined. There are many cases where storage batteries have been introduced either in electric generating stations or in electric substations with substantial and satisfactory economic results. There are other cases, however, where they would not have been introduced or retained if economy were the only criterion. This brings us to consider another function of storage batteries as supplemental portions of electric generating stations and substations, namely, their use for the purpose of diminishing the chances of interruption and the losses incidental thereto, in other words, their value as an additional factor of safety or as an element of insurance against interruption and derangement in the electric current supply.

It is unfortunately difficult to estimate in terms of money the value of storage batteries as a factor of reliability or as a preventive of interruptions, for the reason that this value depends upon the frequency, character, and duration of the interruptions, and the financial losses which result therefrom, which the storage battery may serve to obviate. In some cases storage batteries in central stations have been the means of preventing serious and very costly breakdowns and interruptions of service. It is a fact worth noting, that storage batteries now form an important portion of the equipment of many important central stations furnishing current for lighting and power, and that they also have been introduced in a large number of stations and electric sub-

stations furnishing current for electric railway service. The opinion has been expressed by certain central station engineers and managers that storage batteries were indispensable portions of a generating station equipment and are worth what they cost, on account of the extra safeguard and reserve which they represent. In cases where they also incidentally increase the station economy, their introduction is all the more warranted; but even if they did not show economic results of themselves their introduction would, in the opinion of these engineers, be still warranted as additional factors of safety and as reserve for breakdowns and emergencies. In electric railroad work the prospects are better that storage batteries will have an economic value in addition to their other value as insurance or reserve. The reason for this is that a very much smaller storage capacity may yet suffice to produce an important result in ballasting or equalizing the generator load, thereby producing an increase in the efficiency of the generating plant. The improvement in efficiency will, of course, depend upon and will be governed by the peculiar specific conditions of each case.

The introduction of storage batteries in electric substations has been found of benefit and of utility in another way, namely, in enabling important savings to be made in the cost of the feeder line as well as in the feeder loss. This is an immediate result of the fact that the load of the rotary converters is equalized and that the current transmitted from the generating to the receiving station is nearly constant. With fluctuating loads the same amount of energy is transmitted in a manner which causes a much greater average drop, the consequence being that either the amount and the cost of copper must be increased or else the loss of energy in the line will be greater. Incidentally, the storage battery is an advantage in such cases by enabling a much more uniform voltage to be maintained over the portion of the system which is supplied from the substation. In many cases these considerations would have been sufficient to jus-

tify the introduction of storage batteries in electric substations, even without the incidental economic results.

It is well nigh impossible, in the present state of our knowledge, to lay down general rules by means of which it may be possible to answer all questions concerning the applicability of storage batteries to a given case, regarding the size required, the cost, etc. These questions can only be answered by a careful special study of all the factors and conditions which enter into each individual case.

CHAPTER XIII.

MOTOR EQUIPMENT AND ROLLING STOCK.

Judging by past practices, experiences, and results, it would appear that the all-important details relating to the selection of the motor equipments and rolling-stock for interurban and other electric railway systems were those which received the least consideration from railway engineers and experts. In view of the fact that these are, in general, the determining functions of not only the earning capacity of any system, but of the costs of operation as well, it certainly would seem that engineers should recognize the necessity for, and devote the most painstaking study, application, and efforts to the personal consideration of these details. I know of cases where railway companies having determined upon the use of electricity as a motive power and having intrusted their affairs to civil engineers there have appeared specifications clearly showing that the subjects of electric motor performance as related to schedule speeds and weights were sealed books to the authors of the specifications.

Generally speaking, it is not only poor engineering but absurd to determine a route between given termini, and then prepare a most elaborate set of specifications relating to the construction of the permanent way, stations, and other civil engineering details and then blindly specify that *"the schedule speed of the train units shall be — miles per hour, allowing — seconds for stops at stations."* It is unfortunately true that men practicing as electrical engineers are often guilty of this offense, to characterize it mildly.

While it is true that high-speed railways are now economic imperatives in and around large commercial centers of population, it should never be forgotten that very high schedule speeds with frequent stops are expensive, and, therefore, only warranted in special cases. The schedule

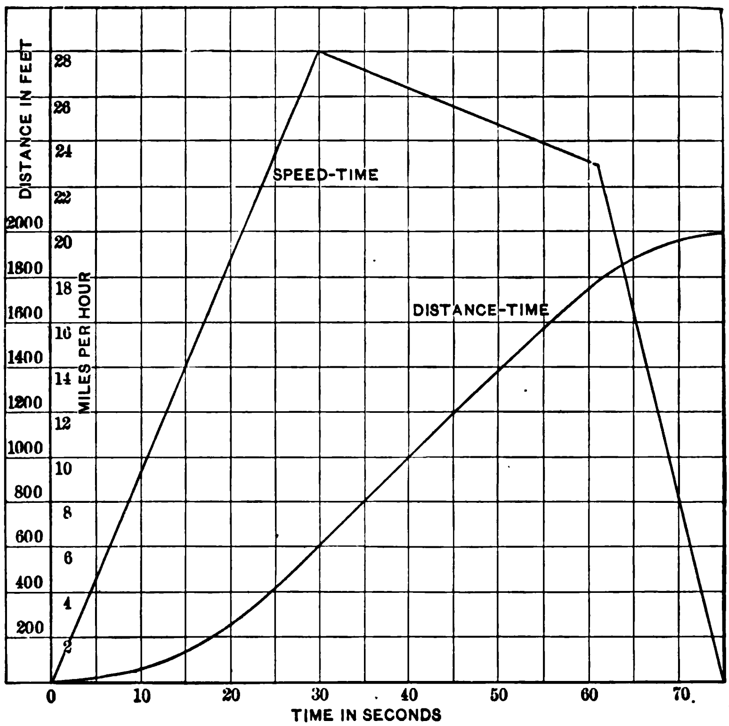
speed affects not only the cost of the motor equipment, but also that of the main generating station, transmission system, and substations. For this reason the matter of the proper schedule speed should always be carefully and exhaustively investigated and determined before it is announced.

The scientific method of procedure consists in first making a rough preliminary determination by assuming the line to be straight and level and the stations or stops at equal distances apart. By assuming certain safe and practically standard data, such as tractive effort, braking effort, time of stops, and train friction, and having the distance between stations, a set of roughly approximate speed time, distance time, and energy curves, can be calculated and therefrom approximations obtained of the energy which will be required to maintain various resulting schedules, and therefrom a set of approximate conditions selected upon which to base the determination of an accurate set of speed-time and energy curves in the construction of which are considered and represented and determined the influence of all the details of alignment, gradients, and stops of the line as surveyed. The engravings on pages 150 and 151, taken from Mr. A. H. Armstrong's paper read at the fifteenth annual meeting of the American Institute of Electrical Engineers, are representations of such first or preliminary approximations. I recommend the study of Mr. Armstrong's paper above referred to, and also the paper entitled "Notes on the Plotting of Speed-Time Curves," by Mr. C. O. Mailloux, read at the nineteenth annual meeting of the American Institute of Electrical Engineers, for detailed information relative to some of the details of the processes and considerations involved in such determinations.

Two or three accurate total run sheets, for runs in both directions between termini, should be constructed before attempting to arrive at a conclusion as to the most economic schedule to adopt. Plates I, II, and III show examples of sections of total runs or individual runs, between two sta-

tions, of such accurate determinations, made in connection with the development of the engineering details of the New York & Port Chester Railroad already referred to.

Such curves also give valuable information relating to the proper gearing of any given equipment for the work

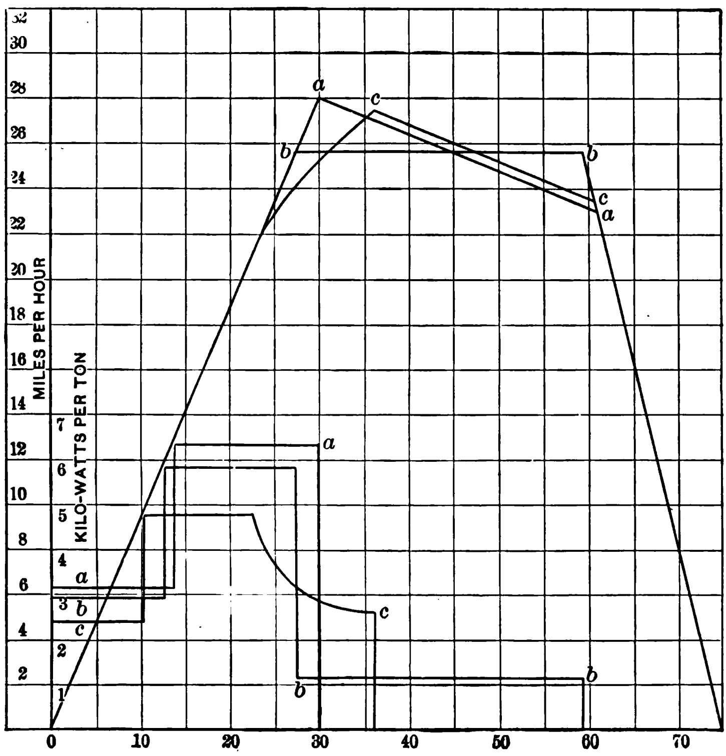


TYPICAL RUN CURVE.

it will be called upon to do. Generally speaking, it will be found that motors should be geared for the lowest maximum speed, allowing a fair margin for occasional required increases due to the necessity of making up lost time, for the making of the required schedule. A gear ratio giving an unnecessarily high speed not only overheats the motors,

but produces unnecessarily great demands upon the transmission system and the generating and substations.

In determining upon a schedule, not only must the matter of motor heating be considered as affected by different rates of acceleration, but there must also be considered and



TYPICAL CURVES SHOWING DIFFERENT ENERGY CONSUMPTIONS FOR THE DIFFERENT WAYS OF RUNNING A GIVEN DISTANCE IN A GIVEN TIME.

determined the matters of the line fluctuations together with those of energy, input and station loads. While rapid accelerations effect marked energy savings it is entirely possible

to wipe out any advantage so obtained on account of the poorer boiler, engine, and generator economies due to irregular load curves and low power factors.

Table III, on page 50, of this volume shows, strikingly, the relations existing between schedule speed, stops per mile, and corresponding energy consumption. In the face of the conditions shown in that table it is difficult to imagine why the matter of schedule speeds has been handled so recklessly by engineers and promoters inaugurating new enterprises. Don't make any public or other promises or statements about the schedules which will be maintained until the matter for the special case in hand has been thoroughly investigated and scientifically determined, even if it is found necessary to retain somebody competent and experienced enough to make the necessary determinations scientifically and accurately. Such determinations embody not only a knowledge of the calculation and construction of "run sheets," but the ability to determine the costs of operation and probable earnings of a proposed system and then determine upon such schedules, etc., as will cause a proper relation to exist between the operating expenses on the one hand, and the gross earnings on the other.

In view of the rapidly increasing maximum speeds at which interurban systems are being operated, attention must also be paid to those details of design which will reduce the train resistance and more especially that element thereof known as "*wind resistance,*" which is by far the greatest component of train resistance. Smooth, flat sides with the platform ends rounded or tapered and enclosed are among the simple and effective methods employed. It is astonishing what a saving in watt-hours per ton mile or per car mile the application of the simple methods above suggested will produce as indicated by recent tests.

The problem of determining the total amount of mechanical resistance opposed to the motion of a car or train is a very difficult one, for which it may be said, in fact, that no general solution applicable to all cases has thus far been

found. It has been generally admitted, for a long time, that this resistance, to which the general term "Train Resistance" has been applied, varies with the speed of a car or train; but there is a wide divergence of opinion in regard to the amount of variation to be expected at different speeds. Many "formulæ" for calculating the train resistance as a function of the speed have been proposed and used. Mr. J. A. F. Aspinall, in his paper on "Train Resistance," read before the Institution of Civil Engineers, in 1901, has tabu-

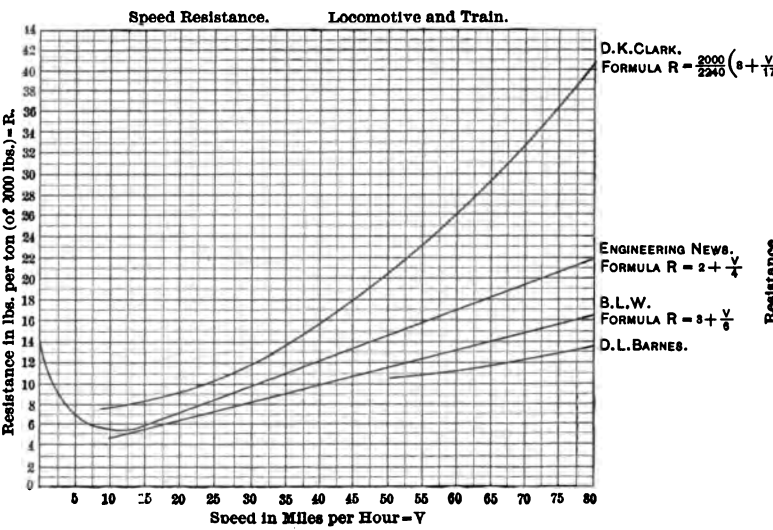
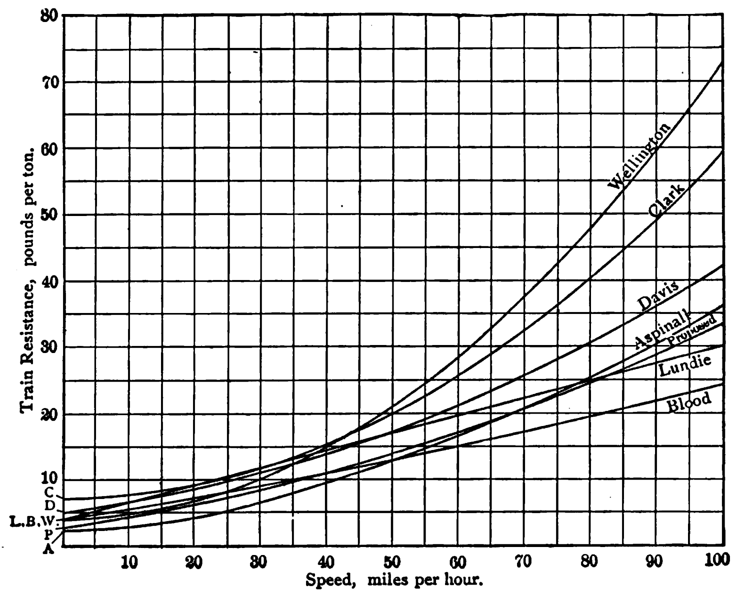


DIAGRAM SHOWING CURVES OF TRAIN RESISTANCE.

lated no less than 55 such formulæ. A complete list would doubtless include twice that number. These formulæ differ greatly in their form and in the purpose for which they are intended. In some cases the formula is intended to give the total resistance, including that of the locomotive and the cars constituting the train. In other cases the formula gives only the resistance of the train. In some cases the formula takes into account only the velocity of the train; in other cases the formula takes into account the

number of cars and the weight and the length of the cars in the train.

The diagram on p. 153 shows four curves of train resistance values, corresponding to four formulæ, which are well known, and which have been much used in steam railroad work. The uppermost curve gives the values obtained by the formula of D. K. Clark, one of the oldest formulæ, and, for a long time, the favorite and generally accepted formula.



CURVES OF VARIOUS TRAIN RESISTANCE FORMULÆ FOR TRAIN OF FIVE CARS.

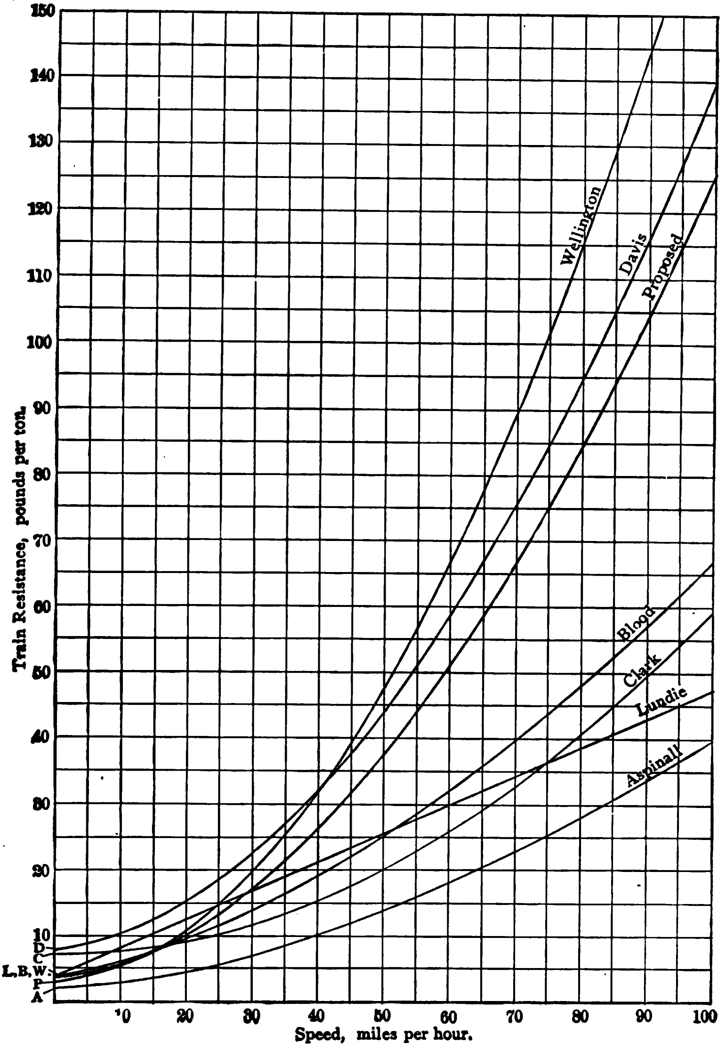
The other three lines represent the values obtained by the so-called "Engineering News" formula, the Baldwin Locomotive Works formula, and the Barnes formula, respectively. The Baldwin Locomotive Works formula is still looked upon as a very satisfactory and reliable one in steam railroad work for long passenger trains. The Clark formula is no longer considered reliable and satisfactory, especially at high speeds, and for long trains.

It is seen that these formulæ make no allowance for the weight of train or the number of cars, both of which are now recognized as important factors affecting the train resistance values. The so-called Wellington formula, proposed by Mr. A. M. Wellington, was one of the first formulæ proposed and used in this country, in which the number and weight of cars were taken into consideration. Various formulæ have since been proposed and used, which include the weight of train, and also the number of cars, or else, the length of train. The most recent, and, perhaps, the most authoritative of these formulæ, is that of J. A. F. Aspinall, given in his paper on train resistance, already referred to.

The development of high-speed electric train service has called attention to the importance and desirability of formulæ which are more especially applicable to electric trains.

Of the formulæ which have been proposed for expressing the resistance of electric trains, the most interesting are those of Davis, Blood, and Lundie. The diagrams on pp. 154 and 156 enable the results obtainable by these formulæ to be compared with each other, and also with the results obtained by various other formulæ. The two sets of curves represent extreme cases. In that on p. 156 the curves are those which correspond to a single car of relatively light weight (25 tons). In this case the atmospheric resistance is very large in proportion to the axle, track, or other resistances. The curves in the diagram on p. 154 correspond to a train of five cars of relatively large weight (45 tons). In this case the atmospheric resistance represents a relatively smaller proportion of the whole resistance. The curve obtained by the Clark formula is the same in both those on pp. 154 and 156. The curve obtained by all the other formulæ is different in the two figures, the resistance values in pounds per ton being, in all cases, lower for the case represented in the diagram on p. 154, than for the case represented in that on p. 156.

The curve marked "proposed" in both diagrams is that



CURVES OF TRAIN RESISTANCE FORMULÆ FOR SINGLE CAR OPERATION.

corresponding to a tentative or provisional formula suggested by Mr. C. O. Mailloux. This formula has a form resembling somewhat the Davis formula, and resembling very closely the Wellington formula. The term expressing the portion of train resistance, which is due to atmospheric resistance, is based wholly on the celebrated experiments of Prof. W. F. M. Goss, with small car models enclosed in a conduit, and subjected to the action of a rapidly moving current or stream of air. In this formula the first term, instead of being constant, varies with the weight per axle, and with the condition of the track.

The formula proposed by Mr. Mailloux has the following form:

$$f=\left(\frac{A}{\sqrt{w}}+g\right)+.15\,V+\frac{(.02N+.25)}{Nw}V^2$$

in which

A = a constant depending upon and varying with the diameter of car wheels and journals.

g = a constant depending upon the condition of the track.

N = number of cars per ton.

V = train velocity.

w = total weight of car in tons.

The value of A varies between 6 and 9.

The value of g varies between 2 and 5.

For approximate calculations corresponding to average conditions, in the case of 8-wheel cars, the formula can take the following simplified form:

$$f=3.5+.15\,V+\frac{(.02\,N+.25)}{W}V^2$$

in which

W = total weight of train.

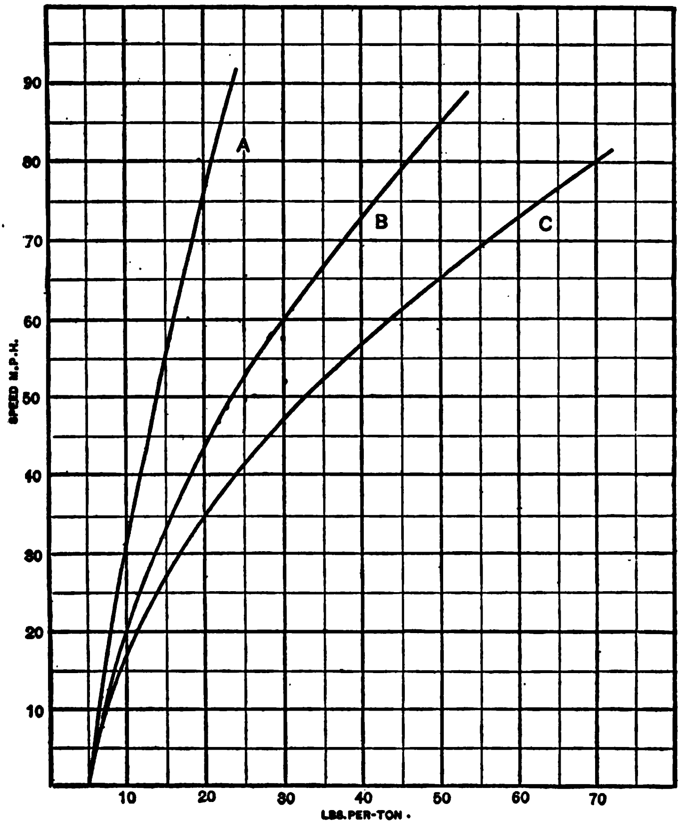
N = number of cars per ton.

V = velocity of train.

Mr. Mailloux has also found that the train resistance values, in any given case, can be expressed with a certain degree of approximation by means of an empirical formula of the form $R = A + B\,V^n$. The objection to this formula

is that the constant (A), the coefficient (B), and the exponent (n) are not fixed, but change in value with each case.

Below are a set of curves, showing the relation between speed and train friction in pounds per ton used by the General Electric Company of Schenectady, New York. These curves represent the results of actual experiments made by the General Electric Company.



CURVES SHOWING RELATIONS BETWEEN SPEED AND TRAIN FRICTION.

The index to the curves is as follows:

A = the operation of 10 or more cars in a train.

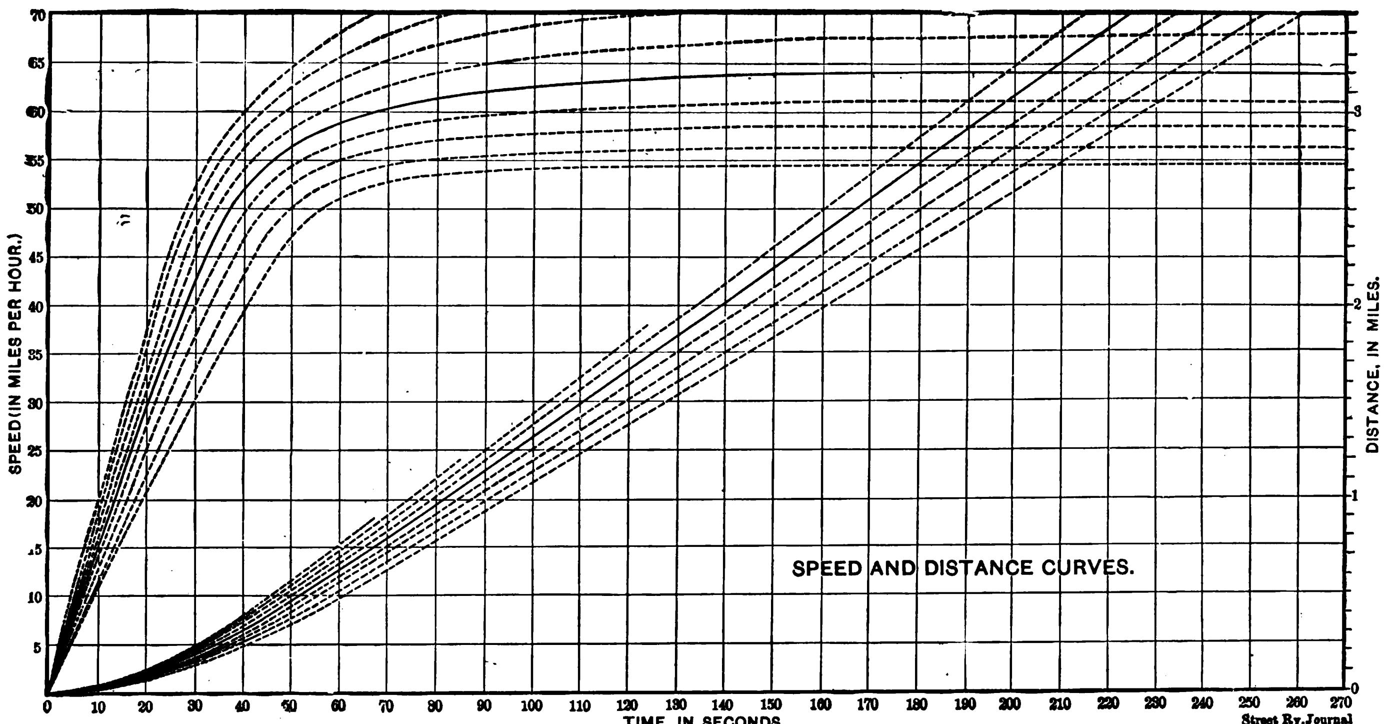
B = the operation of 2 cars in a train.

C = the operation of a single car.

It is assumed that these cars weigh approximately 40 tons each. Mr. A. H. Armstrong states that the curves are accurate up to 60 miles per hour.

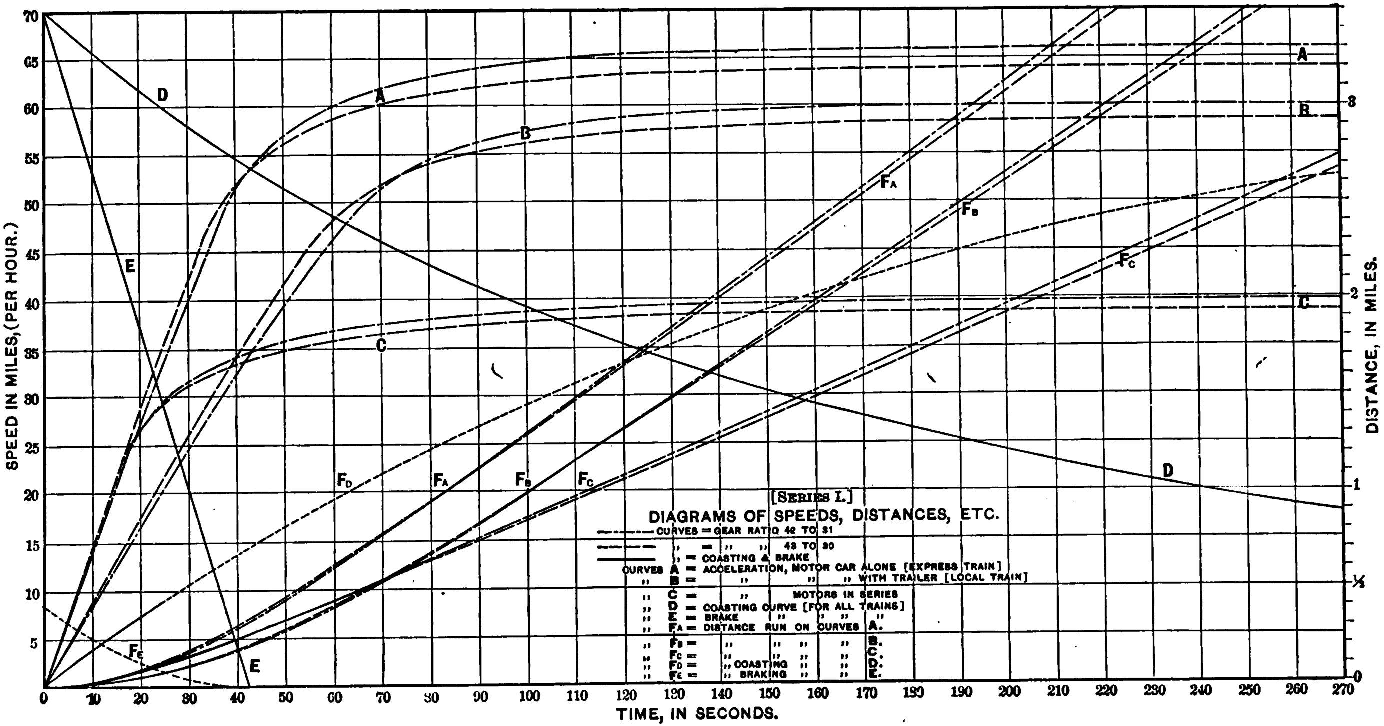
As the matter of determination of the most economical schedule for any proposed installation can only be ascertained by the construction of accurate run-curves, taking into consideration all the elements of alignment, grade, etc., I think it will be well to here indicate the processes involved by showing the construction of an actual run-curve of part of one of the express runs of the New York and Port Chester Railroad Co., between the city of New Rochelle and the village of Larchmont, N. Y., starting at New Rochelle and stopping at Larchmont. This run is shown in Plate II.

In order to construct a "run-curve" a set of computations are necessary. These are shown in Table XIII, which shows some of the data; but only that part relating to the run between New Rochelle and Larchmont is used for this illustration. From Table XIII, it will be seen that the first portion of the run, 0.107 mile in length, is on a 4° curve and on a down-grade of 0.90 per cent. The data in the last column, giving the "correction for curve," show that the advantage of the down-grade is partly lost by the increase in the train resistance resulting from the curve, the result and effect being the same as if the line were straight and had a down-grade of 0.72 per cent. instead of a down-grade of 0.90 per cent. An acceleration curve corresponding to a down-grade of 0.72 per cent., if plotted on the diagram on p. 160, would evidently occupy a position between the first and second upper dotted lines, that is to say, it would come between the acceleration curves corresponding



ACCELERATION AND CORRESPONDING DISTANCE CURVES.

Heavy or full line represents "level" or zero grade. Above the full line are shown the acceleration curves for ½ per cent., 1 per cent., 1½ per cent. and 2 per cent. down grades. The lines below the full line are the ½ per cent., 1 per cent., 1½ per cent. and 2 per cent. accelerations curves for up grades. The corresponding distance curve for each acceleration curve is shown.


[SERIES I.]
DIAGRAMS OF SPEEDS, DISTANCES, ETC.
CURVES = GEAR RATIO 42 TO 31
" = " " 43 TO 30
" = COASTING & BRAKE
CURVES A = ACCELERATION, MOTOR CAR ALONE [EXPRESS TRAIN]
" B = " " WITH TRAILER [LOCAL TRAIN]
" C = " MOTORS IN SERIES
" D = COASTING CURVE [FOR ALL TRAINS]
" E = BRAKE " " " "
" F_A = DISTANCE RUN ON CURVES A.
" F_B = " " " " B.
" F_C = " " " " C.
" F_D = " COASTING " " D.
" F_E = " BRAKING " " E.
SPEED IN MILES,(PER HOUR.)
TIME, IN SECONDS.
DISTANCE, IN MILES.

respectively to down-grades of ½ per cent. and 1 per cent. The most accurate way would be to calculate the data for the curve, and to plot it out in the same manner as was done for the curves shown on the diagram on p. 160. It was found, however, that a new curve could be plotted out with sufficient accuracy by interpolation between the curves shown on this sheet. Thus, if the net percentage had been 0.75 per cent., the curve could be plotted out at points exactly half way between the second and third dotted lines. The curve of 0.72 per cent. would, therefore, come a little under the half-way points. The curve having been interpolated and drawn either on the original diagram or on a piece of tracing cloth placed over the said sheet, the next point was to determine the corresponding distance curve. It is seen from the diagram on p. 160 that the various distance curves are nearly equi-distant from each other. The distance curves corresponding to intermediate percentages could, therefore, be likewise obtained with sufficient accuracy by interpolation. The distance curve corresponding to the required percentage (0.72 per cent.) having been also drawn either on the original sheet or on the tracing sheet, it was cut off at the particular point corresponding on the distance scale to the length of the first portion of the run corresponding to the 4° curve, namely, 0.107 miles. The acceleration curve was then cut off at a point in line with the same time value. The curve shows that the time required by the train in covering this distance was 18.8 seconds, and that the speed attained at the end of this time was 41.7 m. p. h.

The next step was to continue the acceleration curve over the next portion of the run, which, according to the data of Table XIII, is 0.347 mile in length, straight, with no curve, and with a down-grade of 0.90 per cent. An acceleration curve corresponding to a grade of 0.90 per cent. having been interpolated on the diagram referred to, the portion of said curve corresponding to speeds above 41.7 was added to the

first portion of the acceleration curve determined in the manner just described. This second portion was prolonged until the area comprised thereby was equal to the length of said portion, namely, 0.347 mile. The proper point at which the curve should be cut off was determined by reference to the distance curve corresponding to this interpolated acceleration curve, because the difference in ordinate values of the distance curve corresponding to the beginning and the end of the portion of the acceleration curve considered, should be equal, when measured by the scale of miles, to the distance covered. The next portion of the run, as shown in Table XIII, was 0.521 mile in length, straight, and on an up-grade of 0.364 per cent. In this case the interpolated curve would come under the solid line curve in the diagram at a point nearly three-quarters of the distance between the solid line and the first dotted line (corresponding to ½ per cent. up-grade). This curve was used in a like manner to continue the run curve and was in like manner cut off at the proper point, such that the distance covered during this portion of the curve, as shown by the distance curves, was equal to the length of said portion, namely, 0.521 mile. The acceleration curve for the next portion of the run was drawn and added to the preceding portion of the run curve in substantially the same manner. The acceleration was not continued, however, for the entire distance of this portion of the run, the electric power being shut off from the motors after the train had covered a distance of only 0.152 mile on this portion of the run. The relative flatness of the curve in the portion corresponding to the up-grade of 0.364 per cent., and its relative steepness in the succeeding portion (corresponding to a down-grade of 0.433 per cent.), are both the result and the indication of the effect of grades, the relative gain in speed being, as should be expected, much less on an up-grade than on a down-grade. The reason why the electric power is turned off at the point just stated, instead of being continued for a longer time, is that a certain distance must be allowed

for in which to bring the car to a stop. The car is usually allowed to cover a portion of this distance by coasting, which causes the speed to be reduced at a rate varying according to the grade. In this case the coasting is on a down-grade and the coasting curve, corresponding to a down-grade of 0.433 per cent., was interpolated in the diagram of drifting and braking curves, p. 165. It comes close to, but a trifle under, the first dotted line above the solid line which corresponds to a 0.5 per cent. grade. Having drawn this curve, it was added to the other portions of the run curve and cut off at such a point that the corresponding distance covered was equal to 0.415 mile. The next portion of the run, as seen from the data in Table XIII, is 0.183 mile long, straight, on an up-grade of 0.122 per cent. The run curve shows that the car was allowed to coast on the first part of this portion of the run for a distance equal to only 0.061 mile, after which the brakes were applied. The remainder of this portion (0.121 mile) corresponds to the first part of the braking curve, the rest of which curve corresponds to the last two portions of the run, which are, respectively, 0.065 mile long, with 2° curve on 0.122 per cent. up-grade, and 0.063 mile long, straight, on the same grade. The various portions of the brake curve being each straight lines, did not need to be interpolated, as they could be computed, and could be plotted direct from the data thus obtained.

The run curve being completed, the next step was to draw the corresponding electrical energy input curve. This curve is plotted by reference to the kilowatt values obtainable from the input curve on the diagram on p. 166. This curve ends, of course, at the point where the current is shut off from the electric motors, which is the point of highest speed on the curve,— the rest of the distance being traveled by means of the momentum of the car.

The area of the electrical input curve is proportional to the electrical energy, expressed in kilowatt-hours, required

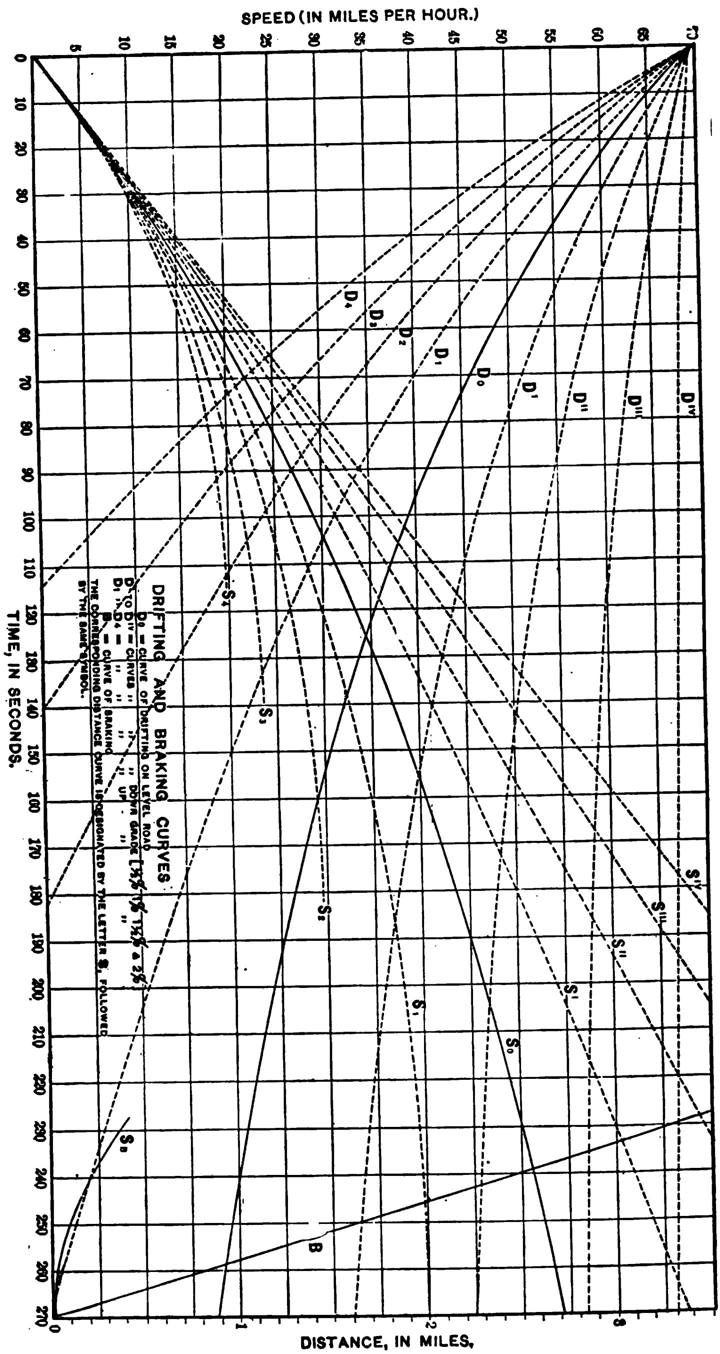
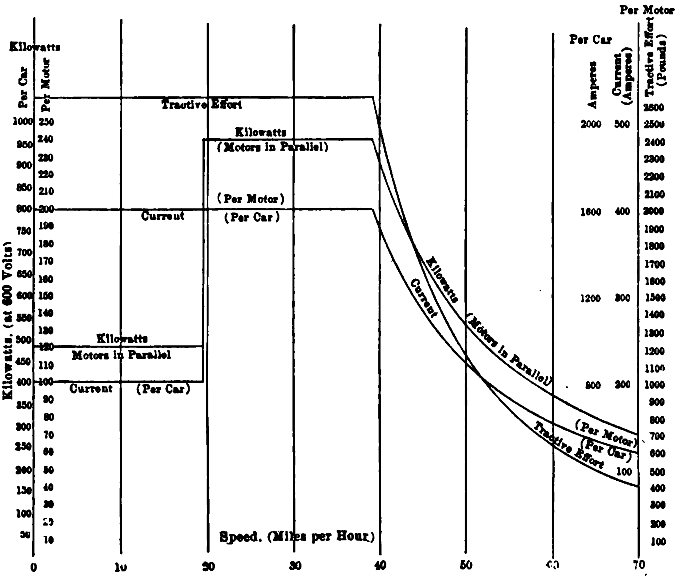


CHART OF RETARDATIONS.

and consumed during this run. In the particular case under consideration, this energy was found, for the run curve for the Express run from New Rochelle to Larchmont, to be equal exactly to 11 kilowatt-hours. The distance of the run being 1.853 miles, and the weight of the car being 52 tons,



CURVES SHOWING ENERGY INPUT AND TRACTIVE EFFORT.

the number of ton-miles per car for this portion of the run would, therefore, be

$$1{,}853 \times 52 = 96.4 \text{ ton-miles.}$$

The energy consumption, when expressed in kilowatt-hours per mile, is equal to

$$11 \div 1.853 = 5.94.$$

and when expressed in watt-hours per ton-mile, is equivalent to

$$11{,}000 \div 96.4 = 114.$$

The process of drawing the run curves, and of making the energy computations therefrom, was substantially the same

for all the other runs. The curves themselves, however, differed for some of the runs in general appearance. Thus, the run curve (Plate III) for the run from Willis avenue to 149th street, also for the Express run from Mamaroneck to Rye Neck (Plate IV), and from Rye to Port Chester (Plate V), show peculiar notches in the middle portions. These notches are due to the fact that there are track curves in the line at various intermediate points between the beginning and end of the run. There is usually a limit to the speed allowable on these curves, which limit depends upon the sharpness of the curve. It is therefore necessary to arrange matters in such manner, that the speed shall be allowed to diminish either by coasting, or by braking, for some time before reaching the curve, to such extent that the speed on entering the curve shall be below the particular limit set for said curve. In the run curve corresponding to the Express run from East 149th street to Bronx park (Plate VI), the acceleration is continued until a speed of over 60 m. p. h. has been attained, at which point the brakes are applied, so as to reduce the speed to a little over 40 m. p. h., at the point of entering the track curve. The power is again applied, and acceleration takes place until a speed of about 63 m. p. h. has been attained, and the current is then shut off and the brakes are immediately applied so as to bring the train to a full stop at the end of the run.

In the run from Mamaroneck to Rye Neck, the power is shut off after accelerating to a speed of about 63 m. p. h., and the speed is then reduced by coasting, the reduction being such that the train enters the first (2°) track curve at a speed of 55 m. p. h., and it continues to coast until the end of said track curve, by which time the speed has fallen down to about 51 m. p. h. The power is then again applied, and acceleration takes place until the speed rises again to 55 m. p. h., whereupon the current is again cut off, and the train is allowed to coast, to reduce the speed in anticipation of the next track curve (4°). By the time this curve is reached, the speed

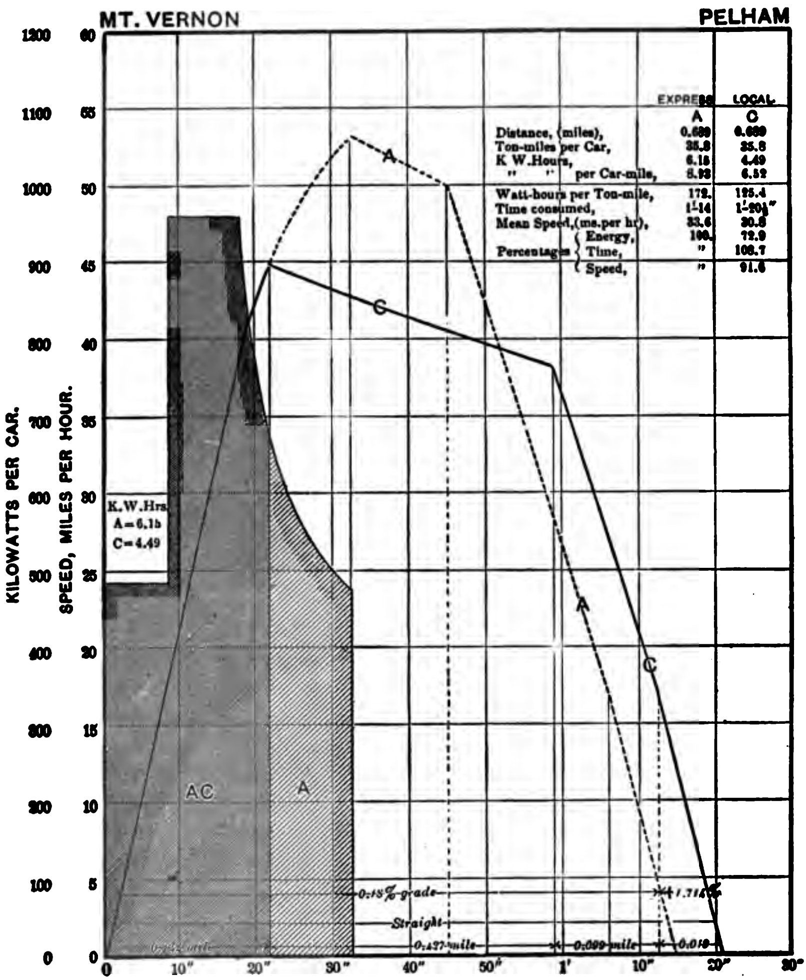
has been reduced to about 43 m. p. h. The train continues to coast until it passes out of this curve, at a speed of about 42 m. p. h., at which time the current is again turned on and acceleration takes place to a speed of about 52 m. p. h., whereupon the brakes are again applied so as to again reduce the speed quickly, in anticipation of the next track curve (3°), which is entered at a speed of about 49 m. p. h., and run over while coasting, after which the current is again put on and acceleration takes place until the time comes for putting on the brakes to make the final stop.

In the case of run curves, such as the preceding one, in which the current is shut off and again put on two or more times in succession, the energy input curves will be made up of different portions or sections, each of which sections corresponds to the time intervals during which acceleration takes place. In the run from Mamaroneck to Rye Neck, the energy input curve consists of four distinct portions. The first portion of the energy input curve which corresponds to the initial acceleration, or the acceleration taking place when the train is leaving the station, has the usual form characteristic of the energy input curve corresponding to the initial acceleration curve of an ordinary run curve, namely, it rises abruptly to the kilowatt value (480 kw.), corresponding to the input current with half the voltage, and remains at this value, as indicated by the horizontal portion of the line, until the point is reached at which the motors become connected in parallel, when it instantly jumps to twice that value (960 kw.), at which value it remains until the point is reached at which the resistance is entirely cut off by the controller, whereupon the values begin to diminish rapidly, as shown by the rapidly descending curve line,— this diminution being due to the reduction of the current as the motor speed increases. In this particular case the descending portion of the curve ends when the current is cut off for the first time at the end of about 78 seconds after starting. The line of kilowatt values

then falls down to zero, indicating that there is no electric current applied to the motors for a period of about 29 seconds, during which time the train is coasting, after which it rises again to the value (about 525 kw.) corresponding to a speed of 50.5 m. p. h. At the end of the second acceleration in this run, when the speed has reached 55 m. p. h., at which time the current is again cut off, the kilowatt value of the energy input curve again falls to zero, that is to say, the energy input curve is again interrupted,— there being, of course, no energy input during the interval of time that the train again coasts (in this case about 35 seconds), in anticipation of entering the second curve and while passing over it. When the train again accelerates after passing out of the curve, electrical energy is again required and the energy input value again instantly rises to the value (about 820 kw.), corresponding to the speed (41.6 m. p. h.) at the beginning of the acceleration. The kilowatt values diminish as the speed increases, same as before, and suddenly drop down to zero at the end of the third acceleration; they again rise at the beginning of the fourth and last acceleration, the highest value in this case being about 590 kilowatts, and the value again drops down to zero at the end of the fourth acceleration, just at the time that the brakes are applied. It is seen, therefore, that the energy input curve in this case is really in four distinct sections, each corresponding to one of the four successive accelerations taking place during this run. The area comprised in the time interval corresponding to each section is usually computed separately. In the run under consideration these areas are as follows:

First acceleration...........	10.81	kilowatt-hours
Second "	1.90	"
Third "	1.83	"
Fourth "	1.76	"
Total	16.30	"

The various portions or sections of the input curve corresponding respectively to the successive accelerations, serve as a measure of the energy expenditure involved and made necessary by these accelerations.



ACTUAL RUN CURVES SHOWING DIFFERENCE IN ENERGY CONSUMPTION FOR DIFFERENCE IN TIME IN MAKING A GIVEN RUN.

The above cases are sufficiently typical to indicate the features of the general method of constructing the run curves for the various requirements of the case. The amount of time required for any given run is influenced by, and depends upon, the maximum speed reached, and the amount of coasting allowed during that run. The aggregate time consumed during all of the runs, plus the total time required for stops, should be exactly equal to the schedule time. If, when the run curves have been made for every run, it is found that the total time, including allowance for stops, is greater or less than the schedule time, then certain modifications must be made in some of the run curves, as may be required to comply with the schedule time requirement. Thus, if the run curves indicate a total time greater than what is allowed for the schedule time, the amount of coasting in some of the run curves must be reduced, and the acceleration must be allowed to bring the speed to a higher point and the braking must begin at a higher speed. If, on the contrary, the curve run shows a total time less than the schedule time, the amount of coasting may be increased, and the maximum speed required, as well as the speeds of braking, may be both reduced; the effect of such reduction being a material consequent reduction in the energy required for the corresponding run, as might be expected from the fact that, when the amount of coasting is increased, the time during which the power is applied to the electric motors is correspondingly reduced.

Four sets of special run curves are here especially shown for the purpose of showing the effect of coasting on the energy consumption expressed in watt-hours per ton-mile. These curves correspond to four runs which happen to be the same length for both Express and Local Trains, as follows:

First: From Willis avenue to 149th street. See Plate III.

Second: From Mt. Vernon to Pelham. See diagram on p. 170.

Third: From New Rochelle to Larchmont. See Plate II.

Fourth: From Rye Neck to Rye. See Plate I.

On Plates I, II, and III three run curves are superimposed on the same chart. The corresponding energy curves are drawn and shaded, and the areas corresponding thereto are shaded in such manner as to clearly indicate to which particular run curve each belonged. These comparative curves show clearly the great reduction in energy required when the amount of coasting is increased and are most eloquent object lessons of the relations of schedule speeds and energy consumption to the economies of operation.

When that part of a run curve corresponding to each individual run, between the stations, has been constructed, a total run curve is made by selecting the desired individual run curves and combining them, allowing the determined time for stops at stations, varying from 10 to 20 seconds between each run. Of course separate individual and total run curves must be made for the runs between termini in each direction.

In determining upon the details of the car equipment and trucks for a railroad system it should be always borne in mind that the source of revenue of the railroad — the Public — is essentially interested in the general appearance of the cars and those elements of their design and construction which will assure to it a maximum of safety and comfort. To attract to themselves a maximum of patronage and especially to secure and hold that powerful asset known as public approval or public good-will, interurban systems must look well to the details of their car equipment. I assume, of course, that the plans contemplate first-class passenger stations and roadbed and properly designed and consequently reliable transmission systems and sources of power.

In determining upon the finish of the cars, the items of subsequent costs of operation and maintenance should never be lost sight of. Excessive ornamentation, filigree work, and fancy figure painting and fancy lettering should be avoided.

Roomy cars, of first-class design, material and construction, finished inside and outside in such manner as to be worthy of the characterization of "*simple elegance*," will do as much or more to make for good earnings as any other two elements combined.

For interurban high-speed systems, having definite stopping places at distances of a mile or more apart, relatively long cars having bodies from 40 to 50 feet long, with 5-foot platforms, will be found desirable. It is not desirable to run open-cars of the existing type on such roads, on account of the inconveniences which would result due to maximum speeds of 45 miles an hour and over. For this class of road, it will be found best to adopt a car having large windows, with the frames so constructed that the sash can be readily lowered or raised, thereby affording to passengers all the advantages of open cars. The question of doors at the middle of the cars has also been discussed pro and con. Generally speaking, middle doors are undesirable for interurban cars, on account of the fact that they require additional platform attendance and thereby increase the operating costs, without affording any proportionate gain. Their use is generally advocated on the plea that they facilitate loading and unloading. This contention is not borne out by the results which have been obtained where they have been tried.

With the advent of high speeds and heavier motors have come the necessity for changes in truck construction. Motor manufacturers will guarantee far more satisfactory results if they be given a truck having a 6-foot 6 inches to 7-foot wheel base, with wheels 36 to 42 inches in diameter, than they can guarantee with 6-foot wheel bases and 30 to 33-inch wheels. The subject of trucks does not appear to have developed as rapidly, or risen to the new requirements as readily, as have other details of the car equipment, more especially those of motors and controllers.

In the matter of trucks as in the matter of permanent way, much time and money will be saved if the engineers

of modern interurban systems will study the best steam-road practice. A recent truck specification prepared by the writer provided for the following dimensions:

Wheels — 36-inch diameter with steel tires.

Tread — $3\frac{1}{4}$ inches.

Flange — $1\frac{1}{4}$ inches.

Axles to be $7\frac{1}{2}$ inches in diameter at wheel seat.

Axles to be $7\frac{1}{2}$ inches in diameter at gear seat.

Journals to be 5×9 inches.

In addition to these dimensions, which indicate the increase in dimensions, are specified the materials to be used and the tests to which the product will be submitted. The standard tests adopted by the Master Car Builders are, in general, used. I believe that the best results will be obtained if the Master Car Builders' requirements be followed for some time to come, for the reason that traffic arrangements and consequent interchange of equipment will soon exist on a large scale between electrically operated and the present steam roads, to the mutual advantage of both the public and the railroad companies. Such arrangements will be facilitated and hastened if the electric systems will design their equipments with that in mind.

TABLE XIII.

Grades, Curves, Etc., for Some Local and Express Runs Going from New York to Port Chester.

NEW ROCHELLE (Express Station).

Run No.		Length in Miles.	Curvature.	% of Grade.		Correction for Curve.
Express.	Local.			Up.	Down.	
7	14	.107	4°		.90	@ .9 = 3.6 lbs. = + 1.180% net = − .90 + .18 = − 0.72%
		.347	Tangent		.90	
		.521	"	.364		
		.567	"		.433	
		.183	"	.122		
		.065	2°	.122		@ .9 = 1.8 lbs. = + 0.09% net + 0.122 + 0.090 = + 0.212%
		.063	Tangent	.122		
1.853	1.853	13.304				

TABLE XIII—Continued.

LARCHMONT (Express Station).

* * * * * * * * * * * * * *

WILLIS AVENUE STATION (Terminal).

Run No.		Length in Miles.	Curvature.	% of Grade.		Correction for Curve.
Express.	Local.			Up.	Down.	
1	1	0.111	Tangent			
		.189	"		1.3	
		.189	"			
		.135			0.283	
		.208	7° 10′		"	@ 0.9 lb. per deg. 6.45 lbs. = + 0.3225% equivalent grade. Net effect = + .04% grade.
		.374	Tangent		"	
		.113	1° 30′		"	@ .9 + .45 = 1.3520 = .0675% net + .283 − .0675 = − 0.215%
		.306	Tangent		"	
1.625	1.625	1.625				

149th STREET STATION (Express Station).

2	2	.378	Tangent	0.348		
		.110	"			
		.133	2° 52′	"		@ .9 = 2.58 lbs. = + 0.129% net = + 0.348 + 0.129 = + 0.477%
		.038	Tangent	"		
		.303	1° 23′	"		@ .9 = 1.24 lbs. = + .062% net = + .348 + .062 = + 0.410%
		.017	Tangent	"		
	.979	2.604				

HUNTS POINT ROAD (Local Station).

	3	.115	Tangent	0.348		
		.114	3°	"		@ .9 = 2.7 lbs. = + 0.135% net = + 0.135 = 0.348 = + 0.483%
		.041	Tangent			
		.265	"		0.286	
		.016	"			
		.107	1° 22′			@ .9 = 1.23 lbs. = + 0.62%
	.658	3.262				

WESTCHESTER AVENUE (Local Station).

	4	.005	1° 22′			@ .9 = 1.23 lbs. = + .062%
		.060	Tangent			
		.567	"	0.433		
		.396	"			
		.086	"			
2.751	1.114	4.376				

TABLE XIII — Continued.

BRONX PARK (Express Station).

Run No. Express.	Run No. Local.	Length in Miles.	Curvature.	% of Grade. Up.	% of Grade. Down.	Correction for Curve.
8	5	.226	Tangent	0.65		
		.424	1°	0.65		@ .9 = 0.9 lbs. = + .045% net = + 0.65 + .045 = + 0.695%
		.084	Tangent	0.65		
		.009	"	0.475		
	.683	5.059				

BEAR SWAMP ROAD.

	6	.542	Tangent	0.475		
		.204	1°	0.475		@ .9 = 0.9 lbs. = + 0.045% net = + 0.475 + 0.045 = + 0.52%
1.429	.746	5.805				

BRONX AND PELHAM PARKWAY (Express Station).

4	7	.156	1°	0.163		@ .9 = 0.9 lbs. = + 0.045% net = + 0.163 + 0.045 = + 0.208%
		.314	Tangent	"		
		.333	1° 9′	"		@ .9 = 1.03 lbs. = + 0.052% net = + 0.163 + 0.052 = + 0.215%
		.125	Tangent	"		
		.043	"		0.561	
		.166	1° 30′		"	@ .9 = 1.35 = + 0.0675% net = − .561 + 0.068 = 0.0493%
	1.137	6.942				

EASTCHESTER (Local Station).

	8	.153	1° 30′		5.61	@ .9 = 1.35 lbs. = + 0.068% net = − .561 + 0.068 = − 0.493%
		.414	Tangent		"	
		.197	"		0.05	
		.190	1°		0.05	@ .9 = 0.9 lbs. = + 0.045 net = − 0.05 = 0.045 = − 0.005%
		.016	Tangent		0.05	
	.870	7.812				

BOSTON POST ROAD (Local Station).

	9	.440	Tangent		0.05	
		.012	2°		"	@ .9 = 1.8 lbs. = + 0.09% net = + .09 − .05 = + 0.04%
		.227	2°		1.52	@ .9 = 1.8 lbs. = + 0.09% net = − 1.52 + 0.09 = − 1.43%
	.679	8.491				

TABLE XIII — Continued.

SOUTH MOUNT VERNON (Local Station).

Run No.		Length in Miles.	Curvature.	% of Grade.		Correction for Curve.
Express.	Local.			Up.	Down.	
	10	.092	2°		1.52	@ 9. = 1.8 lbs. = + 0.09% net = − 1.52 + 0.09 = − 1.43%
		.154	Tangent		"	
		.182	"		0.18	
8.114	.428	8.919				

MOUNT VERNON (Express Station).

The foregoing table is given to indicate, in a few instances, some of the computations and determinations required in connection with the determination and construction of any special set of run curves. The table is given, in part, as it was computed and used. The third column refers to the distance, in miles, from the southern terminus.—W. C. G.

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CHAPTER XIV.

RIGHT OF WAY.

In view of the character of the service which is being exacted of modern interurban railroads, it is not easy to perceive why those responsible for planning and laying out such railways so often persist in selecting public highways for the route, etc. The essential characteristics of successful interurban railways, as already shown, must be:

1. Safety to the public.
2. High schedule speed.
3. Minimum cost of operation and maintenance.

None of the foregoing conditions can be satisfactorily attained where the cars are operated upon or along public highways, upon which pedestrian and vehicular traffic also exists.

Individual or private rights of way are the solution of the problem. The private right of way, however, should be an *individual* roadway throughout, that is, it should be free from grade crossings of all kinds, except at such special points and places where the cars run onto other tracks over which they are to operate.

Interurban roads, to be successful, must be capable of making high speeds, safely and continuously, and this cannot be accomplished where the roadway occupies the public highway, or crosses intersecting highways at grade.

Furthermore, when a railroad owns its right of way it is once and for all exempt from the demands, and continuously increasing impositions of public officials in the matter of annual payments to the local authorities as "*compensation*" for the use of the highways and of repairs to the space between its outside rails, and for various and increasing distances beyond the outside rails. In such matters it has become the practice of some public officials to impose additional burdens every time a given railroad seeks any additional or other privileges in the matter of extensions, track facilities, etc.

I recall several cases where interurban lines have been laid on public highways for considerable distances, when they could have purchased rights of way parallel to the highways upon which they had laid their rails, and but a few hundred feet from such highways, for merely nominal sums ranging between $1,200 to $2,000 per mile. For a road thirty miles in length, a private right of way costing as much as $3,000 per mile will increase the cost but $90,000 for the right of way and (allowing the maximum of three crossings per mile at an average cost of $5,000 each) about $150,000 for the crossings, or a total of $240,000. At 5 per cent. the interest on this cost is but $12,000 per annum. As the items of operation and maintenance must be less for the road using a private right of way, they can safely be left out.

Consider the relative marked advantages which a private right of way 200 to 500 feet from the main road would secure. In the first place a schedule speed three or four times as great could safely be made, and as relatively high speeds and large daily car mileage per car are necessary to secure the best commercial results, for long haul business this is all-important. In the second place the railroad would be free from the petty annoyances, impositions, and demands of ignorant, unjust, or corrupt local authorities. In the third place its property must become more valuable each year as the adjoining territory builds up and settles, and within a comparatively short time it will probably have a railroad through a thickly settled community, upon its own property or right of way, subject to no annoyances, impositions, or charges, except the universal and open real estate tax. In the fourth place it will be in a position to so manipulate and increase its schedules as to enable it to "*get all there is out of the territory,*" and it can also arrange for and take care of any passenger or freight business of any existing or future connecting road or roads. In the case assumed in the preceding paragraph, the additional annual fixed charge

for these advantages is $12,000, plus the annual real estate tax against which must be placed, for the care of a good road upon a public highway, the interest on the first cost of paving between the rails and for the required distance outside of the rails, plus the annual cost of maintaining the roadway as demanded by the local authorities to facilitate vehicular traffic, and it should not be forgotten that the cost of maintaining any roadway subject to vehicular traffic is always in excess of maintenance costs where vehicular traffic does not occur on the railroad roadway. Consequently, we have here two extra additional costs which are: *First.* That of maintaining a paved or macadamized roadway for vehicular traffic. *Second.* That extra cost of maintaining a roadway, such as cost of surfacing, alignment, etc., due to the additional use of the roadway by all kinds of vehicles. To the foregoing debits against the tracks upon public highways must generally be added the annual payment exacted for the use of the highway known as "compensation." In several instances which I have investigated the two accounts were about equal, leaving no doubt as to which scheme to adopt, as in the one case the company would have nothing for its money, while in the other it would have had a real estate asset which would constantly increase in value. In several operating properties which I have investigated I have been able to show that it would pay the companies to buy their own right of way and take up their tracks at the time on the public streets and highways. By so doing they would eliminate the costs of paving, maintaining the paving, etc., and could obtain a far greater revenue per car on account of the far greater daily car mileage per car obtainable on account of the more rapid schedules permissible on a private right of way. In addition there would be eliminated the uncertain, constantly increasing and constantly more serious claims on account of accidents, due to collisions, etc., on account of the development of the territory and the constantly increasing

use of the railroad by the public together with the consequent greater use of the highways by the public.

In the matter of its roadway, the high-class electric interurban cannot possibly do better than adhere to the practice of the best steam roads in this respect. The Pennsylvania Railroad and the New York Central Railroad may be cited as the best example of permanent way and roadway construction.

The use of a right of way frequently involves the exercise of the right of Eminent Domain, by which is meant the right to condemn land. Wherever a railroad company possesses the right of eminent domain, it can and frequently does condemn any piece of property, except that owned by another railroad or a municipality, required for its railroad, where the owner of such piece of land declines to sell the land to the company, or where the price asked for the land is unfair. Before the right of eminent domain can be exercised, it is generally necessary to file with the proper authorities what are known as "property maps," or "right-of-way" maps. Such maps show the transit line, as having been determined, together with a profile of the line showing the proposed sub-grade, that is, the surface on which the ballast is laid, of the railroad. It is generally necessary that such right-of-way maps shall show the last owner of each and every piece of land which will be occupied by the railroad. Such maps are best made to a scale of 200 to 300 feet per inch for the transit line (that is, the horizontal scale). The scale of profile, that is, the vertical scale, can be very well taken as 20 feet to the inch.

The property maps can either be made on a continuous sheet, as is very often done, or they can be divided into a number of separate sheets, each approximately 30 inches by 48 inches. Where a number of separate sheets are used, they are all arranged in proper sequential order, and securely bound together. The maps which are filed are generally either sun prints or blue prints of such sheets. Such

maps are generally required to be filed with the county clerk of each county through which the line of the road passes, that is, a map of that part of the line of the road passing through a given county is required to be filed with the county clerk of that county.

As the separate sheet system can more conveniently be made and upon a very much larger scale, and as any part of the line can be readily altered or changed, I prefer the separate sheet system.

Right-of-way maps are of the utmost importance, and must be prepared with the greatest care. Absolute accuracy is essential, as they are the bases upon which the right of way will be acquired. It is also necessary from a legal point of view that absolute accuracy be attained in the preparation of these right-of-way maps, for the reason that before condemnation proceedings can be commenced, it is necessary that each and every last owner or occupant of the land which will be occupied by the line of the road shall be served with a notice informing him that it is proposed to take his land for railroad purposes. The person so served has the right, at any time within fifteen days, under the law of New York State, after having been served, to appeal to the court, and ask that the line of the road be changed. Such requests are generally not granted unless it can be shown that great and public good will result by the proposed change. When these proceedings have been consummated, all lands shown as occupied, or to be occupied by the line of the proposed road are, at all future times, subject to be taken for the use of the railroad, the filed maps of which show that such lands will be required. In fact, a railroad after having filed its maps, upon completing the legal proceedings indicated above, has practically a lien upon all lands which will be required for its purpose, which are included in the route shown on such maps.

When a piece of land is purchased by a railroad, the deed

should be attached to or refer to a small map showing the part taken. As a matter of fact, in purchasing land, it is necessary that each and every part of land which will be affected shall be individually surveyed. In this respect, the acquisition of land by a railroad company is no different from that involved in the acquisition of any piece of land where great care is always taken to define accurately, the property purchased.

The real estate or land department is a most important part of the organization of a modern steam railroad, and will be of equally great import for such enterprises as are here being discussed.

Many different kinds of maps are required for the proper conduct of the real estate department of a railroad, among which are:

1. Right-of-way maps.
2. Station maps.
3. Land-grant maps.
4. Maps showing gravel pit and borrow pit privileges.
5. Crossing contract maps, showing crossings with other roads.
6. Taxation maps, and numerous others.

The final or permanent right-of-way maps are never made until the line is constructed on account of possible changes in the line during the period of construction.

The procedure generally followed by the real estate department of a railroad in purchasing railroad lands is as follows:

1. An option is obtained from the owner.

2. A careful examination is made of the title. Should the title be defective, the option money is returned.

3. A description of the land to be purchased is drawn, a map thereof is made, and a deed prepared for execution.

4. After the execution of the deed, it is returned to the real estate department, where it is checked and entered upon the proper map or maps, after which it is entered in a

register of land purchases, wherein are shown the names of grantee and grantor, together with a brief description of the premises, the deed of purchase, and the price paid therefor.

Once in the hands of the real estate department, it is filed in the proper files, where it is always readily accessible.

It must be borne in mind that all that has been said about right of way applies to railroads *constructed on private lands*, owned by the railroad company, except where its line or lines crosses public highways.

In many cases the right-of-way maps are prepared and filed very early in the operations of the company. In cases in and around large cities, where the filing of such maps is apt to be taken advantage of by real estate speculators and others, I do not think it advisable to file such maps at the outset. In this regard, I have always found it advantageous to proceed with the determination of the project to the extent of obtaining the required legal and other assents for the crossing of the various highways, etc., which will be crossed by the line of the road, and then, before the maps are filed, proceed quietly and unostentatiously to purchase such lands as will be required by the railroad.

When all the land which it is possible to purchase at fair prices has been acquired, the right-of-way maps can then be filed, and condemnation proceedings proceeded with for such land as the owners will not part with for a fair value.

For the case of conditions such as we have been discussing, the various States generally grant charters for the railroad operating between termini, that is, the termini are specified, and the railroad company is at liberty to make such reasonable alterations in its route as it may deem proper from time to time. Such alterations can always be made with greater advantage to the railroad company before the filing of the final maps.

In connection herewith should not be forgotten what has been said about the right of any property-owner to apply to the court for a change of route. In purchasing

land for the railroad, as indicated immediately above, this right of the property-owner must be borne in mind. It can be seen that acting under that right a considerable portion of the route may be changed, and, consequently, some lands which may have been purchased by the railroad company before the filing of its maps will not be available for its uses along the line which it had determined upon. I think, however, that all things considered, it will be found far better to acquire the right of way before the filing of the final maps, or as much of the right of way as it is possible to acquire before such maps are filed.

In cases where condemnation proceedings are necessary the value of the land is generally determined by commissions appointed by a court. Such commissions must be guided, essentially, by the value of lands adjoining that which is made the subject of condemnation, and of which they are to fix the value. It is a good plan for a railroad company or its operating syndicate to go along its proposed line and purchase odd plots or pieces of land for the purpose of thereby fixing the value of other surrounding property, and thereby not only aid the condemnation commission, but avoid the fixing of exorbitant values. In a very recent case of this kind the railroad company followed this procedure much to the final chagrin and surprise of a number of unscrupulous real estate sharks, who had obtained options upon property which the railroad would require, and then demanded many times the actual value of the property upon which they held options. The speculators, in the case in mind, were finally glad to surrender their claims for what they had paid for them, and, in a number of instances, at an actual loss.

CHAPTER XV.

PREPARATION OF SPECIFICATIONS.

We are now ready to proceed with the preparation of the general specifications, in the event of a decision to let a contract for the construction and equipment and delivery of the road in operation, to a contractor; or else the preparation of each of the detail specifications should the railroad company conclude to do the work of construction and equipment itself. Even should a contract be let to a contractor for the entire work, such a contract, together with the accompanying specifications, almost invariably reserves to the railroad company the right to approve any design or apparatus which the contractor proposes to make use of. This is especially the case where the contract provides that the contractor shall receive a percentage of the total cost of construction and equipment of the proposed enterprise as his profit.

Specifications have been, and often are yet, the cause of much entirely unnecessary trouble, friction, and litigation. Engineers are often prone to attempt to display their technical erudition in specifications. They either do not know, or else disregard the fact that the details of the design and construction of prime movers, generators, transformers, motors, and control apparatus are problems which are receiving the constant application of the brightest detail engineering minds which the large manufacturing companies can secure. The details of the design, development, and construction of electrical apparatus are a life study in themselves. The matter of keeping abreast of and securing for any enterprise the latest approved and most efficient construction and apparatus from the point of view of developed results, is the function of the consulting engineer.

Specifications should specify *Performance,* as it is the

Results that are of essential interest to the owners of railroads and kindred enterprises. Specifiations for prime movers and generators should specify:

1. Type and general character (that is whether A. C., or D. C.)
2. Capacity and overload.
3. Commercial efficiency at various loads.
4. Heating limits (for generators).
5. Excitation (whether separately or self excited and at what voltage).
6. Speed, regulation, and compounding.
7. Approximate floor space.
8. Voltage.
9. Mechanical strength and mechanical features relating to bearings, mountings, etc.

Motor specifications should specify:

1. Capacity and overload.
2. Heating limits.
3. Commutation (for direct current).
4. Maximum weight.
5. Efficiency at various loads.
6. Voltage which will be used.
7. Mechanical strength and mechanical features such as characteristics of bearings, etc.

The development of controlling apparatus is along the lines of the multiple unit type. There are now in use two general types of multiple unit control apparatus.

1. Automatic control.
2. Non-automatic control.

It should be stated that a multiple unit system of control is a system wherein the energy supplied to each or any motor car of a train unit is controlled by an operator (motorman) from any platform or control cab of any motor car unit, or car not supplied with motors where such cars are supplied with control apparatus.

In an automatic system of multiple unit car control, the

maximum rate of acceleration and, consequently, the current limit is independent of the action or volition of the operator or motorman, a condition which may be of importance in the operation of high-speed systems, with relatively short distances between stops. In a non-automatic system the rate of acceleration is controlled by the rapidity with which the controller handle is moved from the "OFF" position to the position of maximum speed.

There are pros and cons for each system as well as instances where one of the two systems is preferable. The automatic system may be a saving safety valve where high schedules with relatively frequent stops are required to be made with indifferent, careless, or ignorant motormen. On the other hand, the non-automatic or hand control gives greater flexibility and enables the motorman to make up lost time by higher rates of acceleration if necessary.

It must not be supposed that a general specification is a document merely skimming over the matter. Such specifications specify essentially performance and only prescribe methods and details where, among a number of different methods and details, certain ones of them are recognized as the best. General specifications carefully prepared by competent engineers and specifying essentially performance and results required, absolutely safeguard the interests of a railroad company about to let a contract *in toto*.

In the appendix an actual specification for an interurban electric road, prepared by the writer, is given. The subject is there divided into the following sections:

1. General description of the line of the road.
2. General description of the plan of construction and equipment.
3. Graduation.
4. Roadbed.
5. Bridges and crossings.
6. Equipment.

7. Stations (passenger).
8. General clauses.

Such specifications not only state the results which are required, but in the case of important installations, as shown in the specification of Appendix I, usually provide for a series of tests to determine whether the requirements as to the efficiency, etc., of the integers such as motors, other machinery and the system as a whole have been complied with.

The details of the construction contract which is based upon the specifications will not here be discussed except to say that it should be drawn up by the best legal talent obtainable. The function of the engineer in its preparation is to prepare for the counsel a brief, setting forth what is desired for such contract. With the digest or brief and the specifications, the lawyer is fully equipped. The less meddling the engineer does with the legal part of such contracts the greater will be his ultimate peace of mind as well as that of his employers.

CHAPTER XVI.

THE CONSTRUCTION PERIOD.

Before and during the construction the railroad company establishes and maintains for the contractor the elevations and alignment finally determined upon. On each stake there should be marked the amount of cut or fill. As the contractor reports on all work his figures should be promptly checked by the railroad company's engineers.

A good plan is to employ a photographer and have a number of photographs made of different places on and along the line before the construction is commenced. On each negative is written the locality together with the date of taking. As the work progresses, photographs should be constantly taken and each negative labeled as indicated. This is done to retain a record of the progress of the work. Such photographic records in connection with accurate diaries may be of inestimable value years later. They are especially apt to attain value where the work is through cities in the event of subsequent damage suits, often intentionally long deferred. In the case of a large undertaking, these photographs often number several thousand, and in connection with a carefully kept diary of the work done, constitute an invaluable record of the status of the construction at all periods of it.

It is also very important that a daily knowledge of the progress of the work should be constantly before the engineer or manager of construction. The best method of keeping and developing the progress of the details of construction is by the use of what are known as Progress Sheets. Such sheets are either in one piece (like a continuous transit line and profile sheet), or are made in sections for convenience in handling and reference (as described in the sectional property maps), and contain the transit line or simply the "line"

as a starting point. A system of colors are then arbitrarily chosen to represent, among others,

1. Graduation started.
2. Graduation completed.
3. Roadbed ballasted.
4. Ties distributed.
5. Track steel in place.
6. Track bonding completed.
7. Third rail insulators in place, etc.
8. Third rail in place.
9. Distributing system completed.

These daily construction operations are indicated by drawing in its proper color adjacent to the existing colored line or lines, the proper succeeding lines each day. The data is taken each morning from the reports required to be sent in by the assistant engineers at the close of each day's work. The advantages of such continuous and complete pictorial records over a system of written reports are too apparent to require comment. Where structural steel work is involved, or where much tunneling is required, or where there are many arches and subways it is only necessary to adapt the color system to these forms of construction which, it is apparent, can be readily done.

Careful records should be kept of the quantity and cost of each kind of work and such costs reduced to a unit basis at some convenient time. Such complete records and data will show the cost per cubic yard for earth and rock excavation, etc.; the cost per foot of pile driven; the cost per lineal foot of structure for concrete or steel structures or both; the cost per unit for laying track and installing third rail, etc. Such individual accurate data, taken in connection with that already noted relating to earnings per capita for different populations, etc., are the stock in trade of the engineer. Contracting engineers or engineers representing contractors generally have the best facilities for obtaining such detail data.

The time for the starting of any new road is preferably during the early months of the summer, or before the summer shall have so far advanced that the pleasure traffic will be lost. There is always an immense amount of pleasure riding during the hot days and evenings of the summer months. If a road can be started early, it is probable that the riding habit can be largely developed during the summer months, a condition which will have a marked and material effect upon the future receipts. Furthermore, the always relatively heavy summer receipts are an agreeable offset, in the minds of the stockholders, to those additional inaugural expenditures which sometimes occur before the operation can be systematized and brought down to a stable basis. The summer receipts also generally more than provide for the first interest payment.

CHAPTER XVII.

THE ORGANIZATION OF THE OPERATING DEPARTMENT.

Before the work of the contractor is concluded, the railway company will necessarily have to commence the organization of its operating department. The subsequent success of any enterprise will depend essentially upon the capacity, characteristics, and experience of the directing heads. Each department should be presided over and the results thereof, as well as every person connected therewith, should be entirely subject to the head of such department. Competent one-man power is always accompanied with good results. All employees of any department should feel that they hold their positions subject to the head of the department. The successful discharge of the functions of any detail department, viewed from the point of view of operating costs, invariably requires men possessing more than technical talents or attributes. A study and a knowledge of human nature and a recognition of and respect for the feelings of others, regardless of their station in life, are often the real controlling factors where the best results are secured.

It is especially desirable to avoid too much organization and especially divided authority. It is safe to say that a majority of the failures in business enterprises are due to either or both of these causes.

It is also well not to forget that transportation systems, and consequently the men in charge of such systems, are the servants of the public, and dependent upon the public. Any disregard of the public is almost certain to be succeeded by some undesirable consequences.

In the operation, as well as during the construction of a railroad, as stated in the preceding chapter, it is of the utmost importance that the chief engineer, manager, or other responsible head of the company should keep himself constantly in touch with and informed as to the progress and

cost of all of the details. In order to do so, accurate detail records must be kept, necessitating the employment of clerks or assistants to daily segregate, reduce, and compile the data. In the case of large roads, the proper keeping of the detail records may require the employment and constant application of a number of assistants for this purpose alone.

One of the most advantageous investments any railroad company can make is that required for the payment of the cost of producing and keeping accurate detail data of the operation of its property. The investment is, of course, that involved in the salaries of the required assistants, together with the materials which will be used in the gathering and reduction of the data. Whenever an engineer or manager is heard to scoff at, and deride such detail data and work, it is safe to say that it is but a question of a short time before he will run his course. Such men are generally too ignorant to appreciate the absurdity of trying to successfully conduct a business without such information constantly before them as will enable them to penetrate each detail, and its variations. Without some detail system, how is an engineer or manager to know where a "leak" or unnecessary outlay is occurring? If a manager does not know where a leak or leaks of a system exist or are liable to develop, his retention is unfortunate for his employers, to say the least. The operating costs as a whole are but the sum of the costs of the separate details, and it is upon the details that attention must be centered in any attempt to affect the operating cost as a whole.

Operating costs are always reduced to a unit basis. For steam roads certain costs are reduced among others to the basis of:

1. *Cost per ton mile,* which means the cost of carrying a ton of freight one mile.

2. *Cost per passenger mile,* which means the cost of carrying a passenger one mile.

3. *Cost per engine mile,* which means the cost of labor, fuel, repairs, etc., for each mile run by a locomotive.

4. Cost per annum per mile of road, or mile of track, as a basis for reducing one of the items of cost of maintenance of way and structures.

Steam roads have a vast amount of other statistical data, such as passenger miles per mile of road; ton miles per mile of road, which are obtained by dividing the total number of miles traveled by all passengers, that is, the "passenger-miles" by the total length of road in single track; or the total number of "ton-miles" by the length of road in single track.

I have here indicated a few of the many units to which operating costs are reduced by steam roads for purposes of comparison, as well as to keep themselves posted about the details of what they are doing. The freight and passenger *receipts* are also reduced to unit bases, by steam roads.

For electric railroad operation the most serviceable unit, and the one now generally used is the Car Mile Unit. Under this system the separate details of the operating costs are reduced to the cost per car mile. The process consists simply in dividing the detail costs of the separate items for a given period by the total car mileage operated for the same period. The car mileage is obtained from the daily reports of the motormen and conductors, which show:

1. The number of the car (or of each car, if trains are operated).
2. The number of trips each car has made.
3. The division over which the car or cars have run.

As the length of each division or "run" is known, from this and with the total number of trips, it is an easy matter to ascertain the daily mileage of each car, and therefrom the total daily car mileage. Such car mileage data are tabulated and entered in the car mileage books each day by office assistants, and this work requires but a short time each day.

To facilitate such work it is a good practice to prepare curves, showing the relation between the number of trips

and corresponding miles run for each division or "run." The data are all then readily taken from such curve sheets. One who has never employed this method will be surprised to find how simple and easy it is to keep up such a system, and far more surprised at the excellence of the results produced, and the value of such data, if the work is intelligently and faithfully done.

For the purpose of facilitating reference to and comparison of such data, the diagram, Plate XI, is shown, on which are graphically represented some such details, for a road operated by the writer some years ago, that is the costs per car mile for:

1. Operation and maintenance of power-houses.
2. The cost of motor repair.
3. The cost of car repair.
4. Costs of motormen and conductors.
5. The receipts per car mile.

These and other details were taken for each month and plotted, using the horizontal axis or abscissa to represent *time*, while the vertical axis or ordinate was used to represent the cost, in cents, per car mile.

For convenience the different lines of the actual charts, representing the various items, were shown in different colored inks. Such accurate pictorial representations are most excellent for use with boards of directors. They very soon grasp the meaning of the rise or fall in receipts or expenses as indicated by the rise or fall of the representative line. In this manner the results being attained, as well as comparisons of such results, are apparent and readily comprehended. This system is far preferable to the use of long rows of figures in parallel columns.

The advantages of the graphical system of representation are manifold. Such a system can be split up and applied to every department of a street railroad, or even electric-lighting installation, and the various heads of departments charged with the keeping of their records in this manner.

The effect of compelling the keeping of such detailed graphical records of each department, by the head of such department, is remarkable and magical.

The value of a knowledge of such differences will be appreciated when, as an instance, attention is called to the fact that railway and lighting installations generally make coal contracts for a period of a year or more. Such contracts specify not only the amount of coal to be delivered within given periods, but also invariably specify the minimum heat value which such coal must have. For the purpose of checking up such detail, as power-house coal consumption, a chart can be prepared similar to that shown on Plate XI, representing various details of street railway operation, but showing on it, by one line, the variations of the kilowatt hours during given periods of time, and by another line, either directly above or below it, the variation in pounds of coal burned during the same periods. If the station efficiency be practically constant, that is, if the same number of pounds of coal is burned to produce a kilowatt hour throughout the period for which the chart is prepared, and, if all other operating details of the plant remain practically the same, then the kilowatt hours and the coal consumption line, if plotted one above the other, will remain approximately the same distance apart, notwithstanding that each will have fluctuations depending upon the output. If, however, through the use of an inferior quality of coal, the station performance becomes less efficient, the result is at once shown by the coal consumption line approaching closer to the energy line, if it is below the latter, or departing from it, if it is the upper line. A graphical method, such as here described, is an easy and apparent check upon such power-house details.

The system can be farther extended to show the condition of the transmission system. The method of procedure would be to ascertain, by a series of dynamometer tests made upon a number of cars, the watt hours required per car mile.

If the equipment be fairly uniform, such as regards length and weight of cars, which is generally the case, a sufficiently close approximation can be obtained for the total watt hours required by the cars, for a given period, by simply multiplying the total car mileage by the number of watt hours required per car mile. On the same sheet, and immediately over this line plot a curve representing the watt hour consumption per car mile at the switchboard. These two lines should remain approximately parallel to each other. In the event of their deviating, it will be well to look to the transmission system, such as the trolley-wire or third-rail connections, or the track bonds.

Again, interesting information can be obtained by plotting one line representing car miles run, another line representing receipts per car mile, and another line passengers carried per car mile. If the last item, that is, the passengers per car mile, be again subdivided into the transfers per car mile and revenue passengers per car mile, some interesting information of the operations of the given system will be shown. If the subdivision, indicated in the last paragraph, be applied to each division of some large system, most valuable information can be obtained, relating to transfer points, etc.

In the construction or operation of a railroad I have always adopted the practice of selecting a certain kind and size (usually 6″ × 8″ or 10″ × 12″) of co-ordinate paper for use for such graphic records as I have just described. All of the records relating to a given detail or set of items are then arranged chronologically and bound together at intervals and for given periods. Thus the annual records of the detail cost of operation per car mile, for various items, and receipts per car mile for the same period are incorporated in a bound volume of thirteen sheets of which twelve are for the twelve months of the year and the thirteenth is a summary of the twelve, representing the variations *per month* and such other additional items as can only be satisfactorily obtained

and represented for such periods as a month. Such bound sets are then supplied to the officers and directors of the company.

Considerable space has been given to some of the manifold and important applications of the diagrammatic representation of the details of the engineering and operation of railroads, on account of its great importance in connection with work of this kind. The successful conduct or operation of a railroad requires, simply:

First. That education, knowledge, and training or experience which enables a managing engineer to know the approximate conditions which should obtain in a properly installed and properly operated railroad or railroads.

Second. That education, knowledge, and training or experience which enables him to penetrate the cause or causes, as well as to know how to remedy any abnormal or improper conditions so soon as they develop.

Third. A method of at once detecting abnormal or improper conditions.

The first two conditions are acquired by study and experience. The third is an almost indispensable adjunct of the other two, and is certainly best obtained by the use of the diagrammatic or graphic methods we have been discussing. As language is but an expression of thoughts, ideas, etc., and as the science of mathematics is simply a language, so such charts may be said to be a language, of the most terse and lucid kind to those who will devote the small amount of time required to understand it.

Reference should also be made to the necessity for periodic, thorough, and comprehensive systems of tests comprising every detail of the installation. As a stitch in time saves nine, so incipient irregularities revealed by systematic tests not only save expensive repairs, and avoid high operating costs, but the unpleasantness of unlooked-for breakdowns and casualties frequently causing cessation of operation, and even loss of life.

In these diagrams and charts the writer has given only a few of the most interesting and commercially valuable applications of a well-known and existing process. Heretofore the process has been confined chiefly to mathematical, laboratory, and other more technical applications, but he trusts that the few valuable applications shown of this simple system will demonstrate to the reader the value of developing habits of thought and research. The result of the proper development of such habits is a Creative Mind, which is the keystone of the successful engineer. The sides of the arch which is maintained by such a keystone must rest on Thought and Learning. Learning, without accompanying or subsequent thought, is labor lost. Thought unassisted, and not directed by learning, is dangerous. Among the stones of the figurative arch we are conceiving must be those of Hard Work, Painstaking Effort, Determination, Application, Uprightness, and Prudence. If the materials for this arch be good and allowed to season, the star of success will inevitably be found firmly mounted upon the keystone.

CHAPTER XVIII.

ECONOMIC CONSIDERATIONS DETERMINING THE MAGNITUDE AND DETAILS OF A PROPOSED ROAD.

Among the most important and trying economic questions relating to the design, construction, and operation of high-speed electric railways reaching well out of the congested centers of population, which the designing and managing engineers are called upon to decide, are those relating to the character of construction and equipment to be adopted, and the character and kind of service to be given.

These considerations may be stated as follows:

1. Number of tracks to be installed.
2. Speed, headway, and size of the train units.
3. Weight of rails and characteristics as affecting costs, of ties, ballast, block system, and other details of permanent way.
4. Character of rolling stock and power stations and transmission system, together with the location and number and character of the passenger stations.

All of the foregoing are functions of the estimated gross earnings of the proposed installation. The earnings must be taken as the starting point. At the present time the plans of some proposed systems appear to indicate a tendency, in some instances, to do too much. There appears to be in some cases a lack of appreciation of the proper relations which should obtain between fixed charges and the estimated gross receipts. In some cases which I have investigated, the fixed charges upon installations, as proposed, equal 40 per cent. to 50 per cent. of the estimated gross receipts, a margin far too close for safety. For the cases of a number of the higher class steam roads in operation the fixed charges are found to vary between 20 per cent. and 30 per cent. of their actual receipts. On account of the demonstrated ability of electric systems to develop business more rapidly than their

steam predecessors the above ratio of the steam lines may at times be exceeded in such cases where the estimated earnings have been conservatively made by experienced engineers. It is always best, however, to keep on the safe side and let the earnings, after the proposed system is operating, do something toward augmenting the installation. If this latter course be followed it is safe to say that the officers and stockholders of the company will not have nearly as many sleepless nights as they otherwise may have should they too ambitiously "reach out and lead." In addition, there will probably be less doing in the receivership and absorbing and reorganization businesses.

Generally speaking, the idea should be to install no more tracks than can be kept busy safely and satisfactorily, taking care of the business in sight and which apparently will accrue from the first few years of development on account of the increased or improved facilities proposed to be given.

In applying the foregoing statement, the question of speed must never be lost sight of. Relatively high speed, being the *raison d'etre* for these roads, must be maintained. Again, in attempting to get as much out of a pair of tracks (single-track roads being out of the question) as possible, it must not be lost sight of that while the capacity of a given installation with a given schedule speed can be increased by gradually adding train units up to a certain point, a limit will be reached, after which, on account of the headway requirements, any increase in the number of units will necessitate a reduction of the schedule speed, and if carried far enough, the carrying capacity will be actually reduced. Any material reduction of schedule speed will probably also cause a loss of traffic. If a schedule speed of 30 miles per hour has been determined upon as that which will be required for a given territory, the idea should be to ascertain the maximum capacity of say two tracks for the proposed road when operating at that schedule speed. If it be ascertained that the two tracks will not be sufficient, at the determined schedule,

to carry the maximum estimated business, then a third track, to be used for express trains going one way during the morning and the other way in the evening, should be estimated upon. It will generally be found that wherever a third track is warranted the conditions will generally admit of the small additional outlay required for a fourth track. The additional costs are those required for the relatively slight additional graduation (earth and rock-work) and the additional rails, ties, and ballast, and the labor of installation. In cases of supplying the suburbs of cities as New York, Boston, Paris, London, Berlin, Chicago, and San Francisco, and similar cities, it will generally be a question of determining whether two tracks or four tracks should be installed, and the safe and conservative solution will always be arrived at by considering the comparative ratio of the different fixed charges which two, three, or four tracks will impose to the probable gross receipts, estimating the gross receipts for the conditions which will exist when the road commences operation. In some instances, where a rapid growth and development is apparent, as about New York City and London, such future development must be allowed for in the original design. As an illustration of such comparisons, I shall assume a set of conditions about as they will be found to arise, as follows:

Suppose the estimated gross receipts of a proposed road are \$900,000 per annum. Suppose, furthermore, that a two-track road could be installed to do this business for \$5,000,000, and that a four-track road would cost \$6,000,000. The fixed charges for the two-track road, at 5 per cent., will be \$250,000 per year, while on the same basis, those for the four-track road will be \$300,000. The annual operating expenses, taxes, and insurance would be about \$500,000 for the conditions assumed for the two-track road, leaving for the two-track road \$400,000 for fixed charges, etc. Deducting the \$250,000 fixed charges of the two-track road would leave \$150,000 annually to be applied to unforeseen contingencies, betterments, and the sinking fund account.

If we assume that we will run approximately the same number of train units between the termini daily for the four-track road at the start, the operating costs will be about the same. In order to justify such an assumption it would, of course, be necessary to reduce slightly the schedule of the two-track road, which can at times be done.

For the case of the four-track road we will then have left, after deducting say $525,000 for the annual cost of operation, taxes, and insurance, the sum of $375,000 for fixed charges, etc. If we now deduct the fixed charges of $300,000 we have left $75,000 for unforeseen contingencies, bad times, betterments, and sinking fund, a margin which is somewhat too small for the solid comfort of the bondholders and the stockholders, especially that of the stockholders. In fact, an enterprise starting upon its career upon the last basis might well be called a "receiver's delight," a "reorganizer's joy," or a "stockholder's obsequies" installation. A four-track installation for the case we have assumed would only be justified where a great immediate development along the line of the road was apparent. Even then the engineer should prepare statements of both conditions, as above outlined, and submit them to the bankers or underwriters so that they will have full knowledge of the relative conditions and contingencies.

The development of large cities and the consequent apparent exceeding of the capacity limits of some existing rapid transit or urban rapid transit systems has offered opportunity for much lay, semi-professional, and even so-called engineering criticism of the shortsightedness of the originators of such transportation systems in not installing more tracks at the time of the original construction. If such critics will investigate they will ascertain that, generally speaking, such roads have been hard pressed for many years to make ends meet, and that they are only now reaping their hard-earned fruits. A little thought will also show that had such systems at the outset provided installations adequate

to do the business they are now receiving, they would certainly, in years past, have suffered financial difficulties to state it mildly. As a general rule promoters and financiers are fairly healthy, and in cases where they are not entirely so there are other and milder means than that of placing large amounts of money in relatively certain jeopardy, by reaching out and leading, of recruiting their exhausted energies. So much for the permanent way.

It is apparent that the matter of schedule speeds, as related to costs of operation, is not generally understood.

The schedule speed may be a large factor in determining the commercial success or failure of an enterprise. As an illustration, by referring to Table III, we see that the watt-hours per ton-mile, allowing a stop every two miles, required for a 40-mile per hour schedule, are 142, while for a 35-mile per hour schedule there are required about 99 watt-hours per ton-mile. If we assume, as an average, a road 30 miles long, over which are made 100 round trips per day, with cars weighing 45 tons each, and assuming a loss of 25 per cent. between the motors and the main power station switchboard and taking the cost of energy at $.006 per kilowatt hour we have $\frac{100 \times 30 \times 2 \times 45 \times 0.006 \times 365 \times 142}{0.75 \times 1000} = \$111,952.80$ as the cost of operating the 40-mile per hour schedule with single car units and $\frac{100 \times 30 \times 2 \times 45 \times 0.006 \times 365 \times 99}{0.75 \times 1000} = \$78,051.60$ as the cost of operating the 35-mile per hour schedule with single units.

The difference between these costs is $33,901.20, which, at 5 per cent., is the interest on $678,024. For a road 30 miles in length, the time between termini for the 35-mile schedule would be 51.4 minutes, while the time for the 40-mile schedule would be 45 minutes; a difference per trip of 6.4 minutes. This matter is also well brought out in the "run curves" shown in preceding chapters and in the plates.

The very best materials and construction only should be employed for the permanent way and the rolling stock, as it

is only by so doing that the maximum safety can be assured to the traveling public, which must always predominate in considering costs of construction. Accidents are always costly, as are also conditions of uncertain operation and delays. The public will not patronize a road upon which accidents are frequent or whereon uncertainty of operation or delay is at all marked. Inferior permanent way and rolling stock is, therefore, equivalent to burning the candle at both ends on account of the natural reduction of receipts, for the reasons stated above, and the additional increase of operating and maintenance costs which always maintain on poorly engineered and poorly installed railways.

Regarding the determination of the details of the passenger stations. Elsewhere in this book, it has been brought out that the location of the stations may have a material influence upon the business which the road will do, depending upon whether the stations are located so as to render them easy of access or otherwise. The matters of the general design, size, finish and specific details of the station will have to be determined separately for each case.

In designing the stations, however, the object should be to provide stations whereon the annual aggregate salaries of ticket sellers and attendants will be a minimum. If ticket offices be placed along each side of the roadway at each station this will not be the case. The stations between the tracks on some elevated systems, known as "island stations," are examples of minimum operation and maintenance cost idea. About half the annual attendance is required for such stations as compared with those on each side of the tracks. The objection sometimes urged against the "island station" system is that people who are so disposed can ride back and forth any number of times after paying a single fare.

In connection with the development of the engineering details, of a road with which the writer has been connected, the tracks of which will be upon a private right of way throughout, and furthermore, upon earth or rock cuts or fills, devised and recommended the following station plan.

Wherever the roadway is on an embankment and above the grade of the streets, the station is to be constructed by providing under the roadway and approximately at right angles to the tracks, a passage-way or tunnel extending entirely across and under the railroad roadway and 50 feet or more, as may be required, in width. The width of this passage-way would, of course, be along the length of the tracks. In the center of this passage-way is to be one ticket office, provided with proper approaches, from each side of the roadway; and inside of and beyond the ticket office are to be waiting-rooms, etc., and the stairs ascending to the island platforms between the tracks. This underground passage-way is to be of the concrete-steel construction. Where the tracks are in a cut, at station locations, and consequently beneath the surface of the streets, the design provided for a concrete-steel structure over and entirely across the tracks, wherein is located one ticket office, as before, with waiting-rooms, etc., inside the ticket office, and stairs descending to the island platforms. Stations of this kind are worth about $8,000 each.

It is evident that the same plan can readily be used for a two-track road.

Where a high speed electric railway crosses a public highway or other railroad, either above or below the grade of the other road, the design of such a crossing, especially where it is below, and consists of a subway of greater or less length, may exercise considerable effect upon the subsequent cost of operation of the system as it may determine the limiting length of the cars where train are used. Elsewhere in this book I have stated that a high-speed road should be designed throughout as to permit of the operation of any of the cars now used by steam railroads and gave my reasons for such a construction. There is, however, another reason of essentially an economic kind. As an illustration, suppose that upon a given road it has been found that on account of the dimensions of part of the subways it will not be possible to use a car more than forty feet in length, and

that train units of three such cars will be required. It is apparent that train units consisting of two sixty-foot cars would carry the same number of people as the three-forty-foot cars, and, allowing one conductor or guard per car, at an operating cost of one man per train unit less. It is easy to see that if train units be operated for any considerable part of the day, the length of the cars becomes a most important consideration and economic factor of the subsequent costs of operation. Mistakes of the kind have occurred and are now practically the cause of considerable additional fixed costs of operation, which could have been avoided had such apparently small details been given that thorough and competent consideration at the outset which their economic importance demands.

The marvelous activity for some years past in the various branches of electric railroading and kindred engineering and financial enterprises has required the frequent retention of engineers and experts for the purposes of making investigations, reports and recommendations. Some of these reports are remarkable for what they do not contain. When a banker, financier, or investor employs an engineer to make a report, it appears to me that while he may be interested to know existing conditions, and the statistics showing results from roads approximately similar to the proposed enterprise he may have in hand, he is essentially trying to find out "*what to do.*" That is, shall he reorganize an existing company, and if so, how much money will be required to do it, and for what, and what will be the commercial and economic result of such reorganization and outlay, and what will be the best plan of reorganization? Or if it be a new enterprise the question simply is: Shall he "go in" and is it "a good safe thing?" and if so, why?

Engineers or experts in making reports often appear to forget or ignore the fact that the essential value of their reports lie in *the conclusions,* and a brief statement of the bases for these conclusions. The body of a report may con-

tain as much statistical detail and general data as may be required to pad out the document to make its outward appearance justify the fee, but the client, upon receiving the document will generally search the index for that part of the report giving the conclusions, and the bases therefor. Often the search is in vain.

Among some reports which have recently been submitted to me for analysis was one consisting of 97 pages of legal cap size paper, and literally bristling with statistics, etc., but which did not contain one positive conclusion or recommendation. The expressions "*it would appear*" and "*it seems*" which have so long and so faithfully served the members of the legal profession have no business in the vocabulary of men representing themselves as railway engineers or experts.

APPENDIX I.

The following specifications prepared by the author for a high-speed electric road between New York and Port Chester have been added:

SPECIFICATIONS.

The work to be done consists in supplying all of the material and labor necessary for the construction and equipment of the railroad of the *New York & Port Chester Railroad Company*, as provided in the following specifications.

The specifications are grouped in subdivisions, as follows:

I. General Description.

The railroad to be built commences at a point in the Borough of the Bronx, at or near the intersection of the elevated railroad with One Hundred and Forty-third street, and runs thence easterly, approximately paralleling One Hundred and Forty-third street, to the easterly side of the Southern boulevard in the Borough of the Bronx; from this point curving, and thence continuing in a northeasterly direction, approximately paralleling Whitlock avenue, of the borough of the Bronx, to the intersection of said Whitlock avenue with Westchester avenue, also in the borough of the Bronx, continuing thence northeasterly and approximately paralleling West Farms road (on the west side, however, of West Farms road), to Rodman place, also in the Borough of the Bronx; curving thence to the right, crossing West Farms road, continuing northeasterly and approximately paralleling Morris Park

avenue in the Borough of the Bronx, to Bear Swamp Road; continuing thence northeasterly through the Borough of the Bronx to a point near the intersection of Kingsbridge Road and Fifth avenue, of Mount Vernon; continuing thence northeasterly through the city of Mount Vernon, village of Pelham, city of New Rochelle, village of Larchmont, village of Mamaroneck, town of Rye, through the village of Port Chester, all in Westchester County, State of New York, to a point on State line, between the States of New York and Connecticut, all as shown on map accompanying this specification, marked Exhibit No. 1.

The railroad is to be built upon a private right of way to be owned by the company, except along such portions of its route where public and existing streets, avenues, and highways will be crossed, at which points the crossings are to be made over or under the grades of such streets, avenues, and highways, as shown on the profile forming a part of these specifications.

The crossings of streets, avenues, and highways are to be made with concrete-steel arch bridges where the tracks are overhead. Where the tracks are underneath, the crossings are to be made of the concrete-steel slab construction, concrete-steel columns being erected between each of the tracks and the outside of the roadway, upon which and the abutments the concrete slabs are to be laid. Should it, for any reason, be found impracticable or undesirable to use the concrete-steel slab construction the concrete-arch construction may be used for the over grade crossings.

Commencing at the southern terminus at or near One Hundred and Forty-third street, as above defined, the roadway shall consist of four tracks, which four tracks shall be carried easterly and northeasterly, as above described, to a point at or near the southeast corner of Bronx Park, in the Borough of the Bronx. Continuing thence from a point at or near the southeast corner of Bronx Park, in the Borough of the Bronx, four tracks will be built on the line as heretofore described, and shown on accompanying drawings, to the terminal station, at or near the intersection of Poningo and King streets, in the village of Port Chester, in the town of Rye, Westchester county, New York State.

A two-track branch line is to be run from the main line from a point at or near the southeast corner of Bronx Park, and running in a southeasterly direction to a point at or near Clason's Point, situate on the East river, in the Borough of the Bronx. The total length of the roadway, including the main and branch lines, will be about twenty-four and nine-tenths (24.9) miles.

There will be, approximately, 17.37 miles of main line, four-track construction, extending from or near the southeast corner of Bronx

Park, in the Borough of the Bronx, northeasterly to the terminal station at or near Poningo and King streets, in Port Chester.

There will be, approximately, 3.51 miles of main line, four-track construction, extending from or near the southeast corner of Bronx Park, in the Borough of the Bronx, southwesterly in the Borough of the Bronx, to the terminal at or near One Hundred and Forty-third street, as above described.

There will be, approximately, 2.8 miles of branch line, double-track construction, extending from or near the southeast corner of Bronx Park, to the terminal of the Clason's Point branch.

The total length of roadway from the Bronx terminal to the State line, including the branch line, will be about 24.9 miles.

There will be, approximately, 91 miles of single track, 84.8 miles of which will be on the main line, and 5.6 miles of which will be on the branch line.

There will be about five miles of additional single track for use as third and fourth tracks about the terminals and some of the stations, and in and about the storage yards, car-barns, etc.

2. General Description of the Plan of Construction and Equipment.

As already stated, the tracks are to be laid upon a private right of way to be owned by the company. The tracks are to be laid having a distance between centers of tracks of thirteen (13) feet. The gauge of the tracks is to be the standard gauge, that is, four feet eight and one-half inches. The rails to be used shall weigh not less than ninety (90) pounds per lineal yard, and shall be of the standard section adopted by the American Society of Civil Engineers. The rail shall be laid upon the best white oak or pine ties, spaced not more than two feet between the centers. The ties shall be laid on ten inches of crushed stone or ballast, and the crushed stone shall be brought up between the ties to a point not less than two inches from the top thereof. The ballast shall be evenly distributed under each track. For two-track construction the subgrade shall be not less than twenty-six (26) feet in width, and for four-track construction the subgrade shall be not less than fifty-two (52) feet in width.

Proper means shall be employed to drain the roadway throughout, and proper provision shall be made along the line of the roadway by the erection of culverts of proper size to provide for the flow of water of any existing or necessary additional water-ways or streams, which shall be crossed by the line of the road.

There shall be installed along the line of the road a block-signal system of the most approved design, preference being given to such a system as will automatically arrest the motion of the train in the event of the operator inadvertently or otherwise passing the signal at danger. The blocks shall be of such length as will be most conducive to the best results of operation under the schedules as herein described.

Telephone lines shall be installed on the company's right of way with the latest improved instruments at every station. A third rail of ample cross section, and the ends of which shall be properly electrically connected, shall be installed along the side of, and at a proper distance from, each of the tracks.

The equipment for this road shall consist of seventy-five passenger cars, fifty-five of which shall be motor cars — the rest to be equipped for use as trailers or intermediate cars.

In addition to the seventy-five passenger cars, the equipment shall include ten box cars for carrying express and freight shipments, five of which shall be motor cars.

3. Graduation.

The graduation shall include all excavations, embankments and other work required for the formation of the roadbed, station grounds, yard and supply works, ditches and drains about or contiguous to the road, the foundation pits of culverts and bridges, for reconstructing public or private highways or roads where the same are destroyed, changed, or crossed by the formation of the railroad; changing the direction of channels and streams, or water-ways, and all other excavations and embankments connected with or incident to the construction of the road.

All work shall be done in a neat and workmanlike manner, and at all times subject to the direction and authority of the New York and Port Chester Railroad Company and its agents or representatives.

Materials from all excavations shall usually be deposited in embankments.

In rock excavations, material shall be taken out to one foot below subgrade, and filled in again to subgrade with selected rock.

Where embankments are made on side hills or upon space of old fills or embankments, steps or benches shall be cut in slopes to prevent the new embankment from slipping, and wherever quick sand, swamps, or springs exist under proposed embankments, the material must be excavated, and the embankment started from firm foundation.

Embankments.— Embankments shall be made from the excavated

material as herein specified, and, as far as possible, started at the base — the full width indicated by the slope stakes — and built to the slope in layers, each not exceeding three feet in thickness.

In depositing filling material against abutments, piers, or walls, such filling material shall always be dumped away from the masonry, never toward it; as the shrinkage of the material is always in the direction in which it flows when dumped, especial care must always be taken to cause the shrinkage thrust to be away from the masonry structures. Where material is tamped or rammed after dumping, the ramming shall be done by vertical blows.

Where there is any special choice of material, the best material should be used at the foot of slopes, on slopes, and on tops of embankments.

Borrow pits.— Borrow pits, when used, shall be confined to such forms as the railroad company may direct, and in all cases a berme of not less than ten feet shall be left outside of the foot of an embankment, and one of not less than three feet wide inside of the railroad company's property line. Side slopes of borrow pits shall be subject to the direction of the railroad company.

The borrow pits shall be uniform in width and regular in form, with provisions for sufficient fall, and for proper drainage to the next borrow pit or nearest water course adjoining the railroad land. Borrow pits shall not be gouged out so as to unnecessarily disfigure the land.

No borrow pit shall be made in or around the stations or railroad yards.

Excavation.— The contractor will be permitted to adopt the open cut or such other methods of excavation as he may prefer, with the following conditions:

1st. Ready access must at all times be given to all fire alarm boxes and fire hydrants along the line of this work.

2d. No two consecutive streets shall be closed at the same time.

3d. Through the tract of land now known as Morris Park, situated between Bear Swamp road and Williamsbridge road, in the Borough of the Bronx, New York City, the contractor must have the tracks upon which the horses run, to the extent of the full width of such tracks which will be crossed by the line of this railroad, as such tracks now exist, in condition that the Spring and Autumn races can be carried on as they now are carried on. That is, there shall be no interruption of the races on account of the prosecution of this work. The contractor shall also leave each race track in Morris Park, crossed by the line of this road, in as good condition as such tracks now are for racing purposes, when the work shall be completed, by providing

under crossings, as herein provided, and back filling with the same material as is now there. The work of crossing the race tracks and finishing the work upon the said tracks shall be done to the satisfaction of the owners thereof.

Such portions of the Quintard and Palmer estates as are located on South Main street, in the village of Port Chester, shall be left as they now are when the work is completed, that is, should an open-cut excavation be there employed, the roadway shall be constructed and completed and the cut then back filled and the surface left as found. The contractor may tunnel through the Quintard and Palmer estates and under the Morris Park track should he desire.

In all cases of tunnels, the space for the passage of the cars shall be fifty-four feet wide (clear inside width), by eighteen feet in height, from the top of the subgrade to the lowest part of the roof, in the event of the arch construction being employed.

The construction of any and all tunnels shall be like that of the under crossings as herein provided.

Slopes.— The character of the ground shall determine the side slopes on embankments and excavations. The slopes must, in all cases, be such as to provide a firm, solid bank, which will not break loose or slide or slip on account of vibrations, or rains, or other causes. In all cases of loose or uncertain embankments or excavating, the contractor shall give the sides such slopes and employ such retaining walls as will produce a structure of the most stable and substantial kind.

Removal of material.— All excavated material not required for embankments or otherwise, in connection with this work, shall be removed by the contractor. Such removal shall be done as the work progresses and all dumping, etc., shall be done in conformity with all municipal or other local and United States regulations, relating to the disposal of such materials within the territory within the jurisdiction of such municipalities or local bodies or the United States government.

Piling.— Wherever piles are used, whether in foundations, or for the purpose of sustaining any part of the roadway or structures, the piles shall be of good quality of sound white oak or other acceptable timber. The piles must be straight, and be not less than ten inches in diameter at the small end, and fourteen inches in diameter at the large end. The piles shall be of such length, as to, in all cases, form a safe and solid foundation for any structure which may be built upon them.

Piles shall be driven with a 2,000-pound hammer, with a fall of twenty-five feet, and must be driven to refusal, or until the total settlement under the last two blows does not exceed one inch.

Wherever pile shoes are necessary, they must be provided by the contractor.

4. Roadbed.

When the graduation is completed to subgrade, the ballast shall then be deposited upon the subgrade.

Ballast.— The ballast shall be of the best crushed stone or other material equally as good. The right is reserved to the contractor to obtain the ballast by crushing such stone as may be required to be excavated for the construction of the railroad wherever such excavated stone shall be of such quality as will produce a ballast equal to the best crushed stone ballast as herein provided for. Such stone, however, shall be crushed so that no stone shall have a greater diameter than three inches in any direction. The contractor shall not use in the construction of this road any ballast which will produce clouds of dust in the operation of the road.

Cross ties.— The standard cross ties are to be eight (8) feet long, six (6) inches wide, and eight (8) inches deep, and to be laid as heretofore provided, with not more than two feet between the centers of ties. All cross ties are to be laid at right angles to the center line of the track. All ties are to be evenly spaced, and the line must be kept on the east ends of the ties. At all joints, selected ties shall be used.

On all viaducts, or in cases where ballast is not used directly under the ties, the ties shall be sawed, having the opposite faces exactly parallel. The dimensions of said sawed ties shall be six (6) inches, by eight (8) inches by eight (8) feet.

Exact length ties shall be used in all cases where special work of any kind is required or installed. In all cases where special work shall be required, extra length ties shall be used to such extent and shall be of such quality as to produce a construction equal to that of the highest class railroad construction used in this country.

The contractor shall also provide extra ties of ample length to provide for the proper mounting or anchoring of the third-rail insulators or pedestals.

The ties used in this construction shall be either the best white oak hewed ties, or the best quality of heart yellow pine tie. Should yellow pine be used, they will only be permitted on the tangent or straight portions of the track. On all curves, and in and about all special work, the best white oak ties shall be used.

Rail composition, length, etc.—The rails shall be of a uniform length, which shall not be less than thirty-three feet at a temperature of sixty degrees (60°) Fahrenheit.

Short rails, to an amount not exceeding 10 per cent. of each shipment, the length of which, however, shall not be less than twenty-four feet, may be used.

All No. 1 rails shall be entirely free from flaws and other defects,

and must be sawed square at the ends, and all burrs made by the saw shall be carefully removed by filing or otherwise, particularly under the head and on top of the flange. All No. 1 rails shall be shipped in cars by themselves, and shall be identified by some characteristic mark.

"Seconds," or No. 2 rails, to the extent of 5 per cent. of the order will be received. All seconds shall be kept separate from No. 1 rails, and shall be shipped in separate cars and be marked with an individual or characteristic mark.

The requirements for all seconds shall be the same as for No. 1 rails, except that they may be accepted with a flaw in the head not exceeding one-quarter of an inch. The company reserves the right to have all rails loaded in the presence of its inspectors.

In all places where it shall be necessary to bend or curve the rail, all such bending shall be done with an approved bender, and in the most approved and workmanlike manner. No springing of rails will be allowed, and wherever necessary to cut the rail, such cutting shall be done with a saw and the ends thereof afterward filed down to a smooth surface so as to avoid all burrs, etc. The rails shall be set throughout on a tie plate placed on each tie, and the said tie plate having ribs running longitudinally with the cross tie. All rails shall be laid with the proper opening at the joints.

Wherever rails are laid during the extreme heat of summer all joints shall be laid tight; and if laid during the extreme cold of winter, they shall be laid one-fourth inch open. When the temperature of the air is at the freezing point, joints shall be laid open three-sixteenths inch; at fifty degrees, open one-eighth inch; at seventy-five degrees, open one-sixteenth inch, and for all intermediate temperatures, the figures above given corresponding to the nearest temperature. Rails shall be laid so as to have a firm bearing on each tie, and shall stand plum on the tie. Each splice must be spiked to the ties through the slots provided for that purpose. Each joint shall have not less than six (6) bolt holes, and all nut locks shall be properly applied.

The composition of the steel used for the rails shall be subject to the approval of the railroad company; qualitative and quantitative analyses of the composition of all steel used for the rails for this railroad shall be submitted to the railroad company when demanded by the railroad company.

Spiking.—The rails shall be spiked to each tie by four spikes, the inside spikes shall be opposite to each other, and the outside spikes diagonally opposite to the inside spikes. All spikes shall be driven straight and firm, so that the heads will have a good bearing on the rail base. Care shall be taken in spiking not to hit the rail with the

spiking hammer, neither shall the rail be hit with the hammer to drive it into position. All tracks shall be laid with broken joints, not less than twelve feet apart. All joints shall be suspended joints.

Gauges.— All track gauges must be correct, and make the gauge exactly four feet eight and one-half inches. The gauge line on the rail is the point on the head, where the curve on the top surface of the rail joins the side of the head. On curves of over four degrees, the gauge of the track shall be widened to one-thirty-second inch for each degree of curvature over four degrees.

Line.— The line shall be perfectly straight on tangents, and all curves shall be of the logarithmic, spiral, or transition type. On all curves an approved design of guard rail shall be used on both sides of each rail, which guard rail shall commence at least fifty feet from each end of the curve, and extend completely around the curve.

In general the elevation of the outer rail on curves shall be one inch for every degree of curvature, with a maximum elevation of seven inches. The full elevation of the curve should not be given at the P. C. or P. T. The point at which to commence the full elevation is approximately where the tangent offset from the tangents at each end of the curves equals one inch.

Surfacing.— In surfacing the track, the ties shall be tamped one shovel width inside of the rail. The ends of the ties outside of the rail shall be uniformly tamped to a solid and uniform bearing. On tangents, the tops of the rails must be exactly level, except in approaching curves, where the rail leading to the outer rail on the curve must be made higher than the inner rail, at the rate of one inch to every thirty-three feet, so as to meet the full elevation given in the curve.

Special work.— Trailing crossovers shall be installed at points approximately five miles apart at each set of tracks, but at such points as the railroad company may direct. At all the principal stations, such as New Rochelle, Mount Vernon, Mamaroneck, and the termini, trailing branch-offs shall be installed connecting the main line with such branch line tracks as may be determined upon, which, however, shall not exceed two extra tracks at each of the principal stations, and four extra tracks at each of the termini.

All special work used for crossovers, turnouts, and side tracks in and about the yards, car-barns, etc., shall be of the best material and workmanship equal to that of the best manufacture in the country. No cast iron frogs, joints, or mates shall be used. All special work, such as crossovers, branch-offs, spurs, etc., shall be protected by heavy wooden stringer guard rails, braced and anchored and fastened to the ties in the most substantial and approved manner.

An extra track, connected to the south-bound track of either the local or express tracks, as may be determined by the railroad company, having a capacity for twenty cars, shall be constructed immediately north of the station located and constructed in Morris Park, as herein defined.

An extra track, having a capacity of not less than six cars, shall be constructed at each express station.

Loops at terminals.— At each of the terminals on the main line, together with the terminal of the branch line, the contractor shall install loops of ample radii to permit easy passage of the train units. These loops shall be so installed as to facilitate to the utmost the moving of the train units in and about the termini. The contractor shall install at each terminus in such manner as will most facilitate the operation, additional tracks sufficient to store at least three trains of four cars each. These storage tracks shall be so designed and installed that the extra trains may be safely, quickly, and easily run out and placed in service whenever it shall be necessary.

Rapid Transit Subway connections.—At or near the southeast corner of Bronx park, at the point finally determined upon by the railroad company, the contractor shall make provision for the depression or elevation of such of the tracks of the New York and Port Chester Railroad, as will be finally determined upon for use for the express service. The object thereof is to provide for the connection, avoiding crossing at the grades thereof the remaining tracks of the railroad as herein provided, of the two express tracks of the New York and Port Chester railroad with the tracks of the New York Rapid Transit Subway, at or near the crossing of the said Rapid Transit tracks with One Hundred and Seventy-seventh street in the Borough of the Bronx.

The Rapid Transit Subway Construction Company will install two extra tracks on its structure for the purpose of making this connection. These tracks will be installed by commencing at a point approximately One Hundred and Seventy-fifth street, and running thence northwardly on a gradual descending grade, so that the two extra tracks will pass under the Rapid Transit Subway structure at or about One Hundred and Seventy-seventh street. Provision shall be made by the contractor and he shall connect two of the tracks of the New York and Port Chester railroad with the rapid transit subway tracks at or near One Hundred and Seventy-seventh street, where the two extra rapid transit tracks terminate, as herein above stated. Provision shall also be made by the contractor to enable the New York and Port Chester Railroad Company to connect its tracks with the proposed east side branch of the New York Rapid Transit Subway. The contractor, how-

ever, will not be expected or required to make any provision for the connection of the proposed east side branch extending beyond the terminus at One Hundred and Forty-third street, as herein provided. He will be expected and required to make such provision that this connection can be made when the east side branch of the New York Rapid Transit Subway shall be under construction.

The contractor will also provide and make a physical connection between the tracks of the New York and Port Chester Railroad Company at some point to be determined upon between East One Hundred and Forty-first street and East One Hundred and Forty-third street, in the borough of the Bronx, and the tracks of the Manhattan Elevated Railroad Company, where such tracks of the Manhattan Elevated Railroad Company cross East One Hundred and Forty-first street and East One Hundred and Forty-third street, in the Borough of the Bronx. This physical connection between the tracks of the New York and Port Chester Railroad Company and the tracks of the Manhattan Elevated Railroad Company to be independent of the terminal and terminal tracks of the New York and Port Chester Railroad Company to be provided by the contractor, in the Borough of the Bronx, at some point between East One Hundred and Forty-first street and East One Hundred and Forty-third street as herein provided and as shown on the accompanying map, Exhibit I.

The details of the design and construction of the connections with the Rapid Transit Subway, and the Manhattan Elevated Railroad as herein provided, shall be submitted to and approved by the New York and Port Chester Railroad Company before any work shall be commenced thereon.

Avoidance of crossing all tracks at grade.— In and about junction points and at all termini, the contractor shall so design and install the work that the express and local tracks will not cross each other at grade. In all such cases, one set of tracks shall be depressed or elevated should it be necessary to pass across the other set of tracks.

As the express tracks are to be connected with the tracks of the Rapid Transit Subway Company at or near One Hundred and Seventy-seventh street and Boston Post Road, in the Borough of the Bronx, and as the express tracks are to be continued southward to the southern terminal, the contractor shall, at a point on the express tracks between One Hundred and Seventy-seventh street and Bear Swamp road, provide for the extension of the express tracks southwardly beyond the connection with the Rapid Transit Subway tracks at or near One Hundred and Seventy-seventh street, as herein provided, by constructing two extra tracks, connecting with the express tracks, and carrying these two extra tracks at the same grade as the local tracks to the southern terminus, and thereby allowing the two express tracks, connecting with

the Rapid Transit Subway tracks at or near One Hundred and Seventy-seventh street and Boston Post Road, as herein provided, to pass over or under the express tracks continued southwardly to the southern terminus in the same manner as the two said tracks will pass over or under the local tracks, as herein provided.

The connection of the branch line to Clason's Point, as herein provided, with the express or local tracks, as may be finally determined, shall be made without crossing any of the other tracks at grade.

The tracks of the branch line shall be connected with the main line tracks with a Y connection so as to provide for a continuous service from either the northern or southern terminus of the main lines to the end of the branch line.

All designs for connections and crossings, avoiding grade crossings, shall be approved by the railroad company before the work thereon is commenced.

Bonding.— The track and third rail shall be bonded with the best bonds obtainable, such bonds to be of a size sufficient, and so made and installed that one square inch of radiating surface shall be allowed for each 800 amperes passing through the bond.

Fencing.— The entire right of way shall be fenced in. The fencing shall be of a strong construction and of such kind as will keep the general public off of the right of way. The fencing in of the right of way does not, of course, include that part of it occupied by stations.

Wooden trestles, etc.— As the object of these specifications is to provide a roadbed and structure of the most substantial construction, and whereon the cost of maintenance of way and structures shall be a minimum, no wooden trestles, bridges, or spans will be allowed. The tracks and structures shall be located and constructed upon the most substantial earth, rock, steel, and masonry beds, structures, and foundations. Where absolutely necessary, steel viaducts of the most approved design and construction may be used. The permission, in writing, of the railroad company shall be obtained in each case where steel viaducts are proposed before the commencement of the construction thereof. This clause is not intended to prevent the use of any temporary wooden structures erected for the purpose of facilitating the work, but such temporary structures shall be removed when the road is tendered for acceptance to the railroad company.

5. Bridges and Crossings.

As already indicated in the general description above, the crossings, either over or beneath the grade thereof, of all public streets, avenues,

and highways, shall be made with concrete-steel bridges. All bridging of streams shall also be made with the concrete-steel structure.

It is, of course, possible that in some instances, where the crossing of a highway will have to be made on a long skew and where, on account of such a condition, the angle of repose will be too closely approximated, it will be more desirable to insert a steel crossing. It is understood that this may be done in cases where it shall be absolutely necessary, but in no case shall a steel crossing be inserted without the express permission, in writing, of the railroad company.

Concrete.— All concrete shall be made of the best quality of Portland cement, sand, and broken stone. The proportions will generally be one part of cement, three of sand, and five of broken stone. The stone shall be of such size that the largest stone shall pass through a two-inch ring. Before any stone shall be used in this work, it shall be entirely freed from dust by being screened or washed out. All stone used for concrete shall be hard and durable and free from seams and shall be at all times subject to the approval and rejection of the railroad company. All concrete shall be thoroughly mixed and well made, and well rammed before any initial set of cement takes place.

All concrete shall be deposited in regular layers of not over six inches thick and rammed, and the surface of each layer shall be kept clean for the deposit of the next superior layer.

In laying the concrete and in ramming the same, the ramming shall continue until the water flushes to the surface. In all cases, before laying any concrete on rock surfaces, the rock shall be swept clean of all débris and dirt, and wherever it shall become necessary to lay fresh concrete next to, or on top of, concrete in which the mortar has already set, the surface of the old concrete shall be well washed and a thin layer of clean cement shall then be spread over it immediately previous to the laying of the fresh concrete.

All sand used in the preparation of concrete or elsewhere in this work shall be coarse, clean, sharp sand, free from loam or foreign matter, and shall, at all times, be subject to the approval of the railroad company.

In cases where the crossing of any street, avenue, or highway shall be beneath the surface of the street, that is, shall be an under-crossing, such crossings shall be made as shown on the general plan accompanying these specifications, entitled "General Plan for Crossings Beneath the Surface of any Public Highway." In general, this plan contemplates the erection of concrete-steel columns between each pair of tracks, together with concrete-steel abutments at such a distance from the outside rail of the two outside tracks, as is shown on the drawing above re-

ferred to. All these columns are to be proportioned to carry the live and dead loads which they will have to sustain.

Under street crossings for four track construction shall be fifty-four (54) feet clear inside width, that is, the distance between the inner surfaces of the outside walls shall be not less than fifty-four (54) feet, and eighteen (18) feet in height from the subgrade to the lowest part of the under side of the roof.

Under street crossings for two track construction shall be not less than twenty-eight (28) feet in width, and eighteen (18) feet in height from the subgrade to the lowest part of the under side of the roof.

All metal used for any of the steel structures of this work before leaving the shops, shall be thoroughly cleaned with wire brushes and have all loose rust or scale removed, and be given one coat of pure red lead, and pure boiled linseed oil, mixed in proportion with thirty pounds of red lead to a gallon of oil. After erection, the metal shall again be cleaned from dirt and objectionable matter that may be found thereon, and then thoroughly and evenly painted with two additional coats of paint.

All metal used for concrete-steel structures must be free from paint and oil and all scale and rust must be removed before imbedding in the concrete.

All overhead crossings of highways, streams, and in fact wherever such crossings shall be used, shall be approved concrete-steel structures, the general design and appearance of which is shown on drawing accompanying these specifications, marked "General Drawing for Overhead Crossings." All such structures shall be constructed in the most substantial and workmanlike manner and of the very best materials obtainable. All designs shall at all times be subject to the approval of the railroad company.

After the forms shall have been removed, the structure shall be carefully gone over and all inequalities carefully filled out in such manner as to produce a final structure of the neatest possible appearance. In all cases where forms are used, every precaution shall be taken in setting the forms. Before any concrete is placed therein, they shall be carefully cleaned of all cement and dirt, so as to present to the concrete on the surface afterward exposed to sight, a perfectly smooth surface. The forms shall be made of wood, kept smooth and coated with soap or other suitable substances approved by the railroad company. No sheet metal-covered forms are to be used on the work. All forms shall be set true to the line, and be so tight as not to allow mortar and the water to escape. Forms shall always remain in place until the concrete is thoroughly set; in the event of any

pressure coming at once on the concrete, such time as the railroad company may direct. In no case of an exposed surface of the concrete, shall the joints of any component bases of the form or joints of the wood be visible. Should any voids or irregularities appear after the removal of the form, such defective work shall be cut out and filled with a rich concrete or mortar of such proportion, and done in such manner as may be directed by the railroad company.

Parapets, spandrels, arches, etc.— For all subways or over-grade structures, concrete parapets of the form and dimensions shown on plans shall be brought true to the line and be firmly fastened in the position shown. These parapets shall be erected on each side of structure along the property lines of the street, and extend from end to end of retaining walls. For all arches or under-grade structures, no parapets will be required. The spandrel walls shall be carried up to the elevation of base of rail, and shall be provided with expansion joints over the springing lines of the arches, at the points of contra-flexure, and at such other points, if any, as are shown on plans. The spandrel walls shall have a thickness of not less than eighteen inches at any point, and a thickness at bottom of not less than four-tenths of the height of the wall. Steel ribs or rods of proper and approved design, dimensions, construction, and spacing shall be imbedded in the concrete of all arches.

Each spandrel in arch bridges shall be provided with one or more pieces of wrought-iron pipe for the conveyance of such electric light conductors as shall be required for such lights as the railroad company shall order installed on the arches.

In all cases where new concrete shall be joined to old concrete, the old concrete shall first be thoroughly washed and then covered with a layer of clean cement upon which the new concrete shall be placed. All concrete shall be kept moist by sprinkling and every precaution taken to prevent it from cracking.

Cement.— No cement will be allowed to be used except established brands of high-grade Portland cement which has been in successful use under similar conditions to the work proposed for at least three years, and has been seasoned or subjected to aeration for at least thirty days before leaving the factory. All cement shall be dry and free from lumps, and immediately upon receipt shall be stored in a dry, well-covered, and ventilated place, thoroughly protected from the weather. If required, the contractor shall furnish a certified statement of the chemical composition of the cement, and of the raw material from which it is manufactured.

The fineness of the cement shall be such that at least 90 per cent.

shall pass through a sieve of No. 40 wire, Stubbs gauge, having 10,000 openings per square inch, and at least 75 per cent. will pass through a sieve of No. 45 wire, Stubbs gauge, having 40,000 openings per square inch.

Samples for testing may be taken from every bag or barrel, but usually for tests of 100 barrels a sample will be taken from every tenth barrel. The samples will be mixed thoroughly together while dry and the mixture be taken as the sample for test.

Tensile tests will be made on specimens prepared and maintained until tested at a temperature not less than sixty degrees Fahrenheit. Each specimen will have an area of one square inch at the breaking section, and after being allowed to harden in moist air for twenty-four hours will be immersed and maintained under water until tested.

The sand used in preparing test specimens shall be clean, sharp-crushed quartz retained on sieve of thirty meshes per lineal inch, and passing through a sieve of twenty meshes per lineal inch. In test specimens of one cement and three sand, no more than 12 per cent. of water by weight shall be used. Specimens prepared from a mixture of one part cement and three parts sand, parts by weight, shall, after seven days, develop a tensile strength of not less than 170 pounds per square inch, and not less than 240 pounds per square inch after twenty-eight days. Cement mixed neat with from 20 to 25 per cent. of water to form a stiff paste shall, after thirty minutes, be appreciably indented by the end of a wire one-twelfth inch in diameter loaded to weigh one-quarter pound. Cement made into thin pats on glass plates shall not crack, scale, or warp under the following treatment: Three pats will be made and allowed to harden in moist air at from sixty to seventy degrees Fahrenheit; one of these will be placed in fresh water for twenty-eight days, another will be placed in water which will be raised to the boiling point for six hours and then allowed to cool, and the third is to be kept in air of the prevailing outdoor temperature.

6. Equipment.

The equipment shall be of the very best design and workmanship, and subject throughout to the approval of the railroad company.

The equipment shall include all rolling stock, motors, boilers, engines, wires, conduits, mechanisms, tools and implements, and devices of every nature whatsoever which may be necessary for use in the transmission of the motive power, and operation and most economical maintenance and conduct of the railroad as proposed, and including all power-houses, car shops, repair shops, terminals, and real estate neces-

sary therefor, and all apparatus for signaling, and any and all apparatus whatsoever, of whatsoever kind and nature which may be required for the best operation of the railroad as designed and as provided or implied in these specifications.

The passenger car rolling stock provided shall consist of seventy-five passenger cars, fifty-five of which shall be motor cars, and each motor car shall be equipped with four motors, that is, one on each axle, and of such capacity as will enable it to make, when drawing one of the trail cars, and both cars together carrying 200 passengers, a schedule speed of not less than thirty miles per hour, for the express service, when such express service shall be operated as now designed, making ten stops between the termini, and allowing fifteen seconds for each stop. In addition to the above seventy-five passenger cars, the contractor shall provide ten additional freight and express cars as herein provided, making eighty-five cars in all.

The passenger-car equipment provided by the contractor shall be of ample capacity to enable it to make, with units consisting of one motor and one express car, for the local service, a schedule speed of not less than twenty-five miles an hour, making twenty-one stops between termini, and allowing fifteen seconds for each stop.

Each of the motors provided by the contractor for this equipment, as herein provided, shall be of such a capacity that each or any of them will carry a current of 350 amperes at 600 volts continually for two hours, with a rise of temperature by thermometer not exceeding seventy-five degrees Cent. The weight of each of the motors provided by the contractor for this equipment shall not exceed 6,000 pounds per motor, including the weight of gear pinion and gear case.

Brakes, etc.— All the cars provided by the contractor for this railroad shall be provided with the latest and most approved automatic power braking apparatus. All braking apparatus used on any part of this equipment shall be equal to that of the best manufacture in the United States, and shall be submitted to and approved by the railroad company before its adoption or use by the contractor.

The braking apparatus shall be such that all of the brake shoes of a train of any length will be instantly applied by the application of the brakes from any platform of any car.

Unity of equipment.— In the selection of the motor and car control equipments for the performances of the express and local train services, as herein provided, the equipments adopted shall be such that all motors and motor-car units shall be the same as regards capacity, weight, size, and dimensions, that is, there shall be no mixing of motor or control equipments or braking equipments.

The motive power shall be electricity, of either the direct or the alternating current system,— whichever system shall be determined upon by the contractor and approved by the railroad company. The details of the motors, controlling devices, and primary and sub-stations shall be submitted to the railroad company, and shall receive the approval of the said company before their adoption by the contractor. The railroad company shall have the right to adopt such improved designs, devices, paraphernalia, in connection with this equipment, as it shall desire, and all such devices and designs so ordered by the railroad company shall be adopted and used by the contractor if ordered to do so prior to the acceptance of such apparatus as the contractor may submit.

The cars used shall be neat and attractive in appearance, both within and without. All material and workmanship shall be of the very best and latest design, and special care shall be taken to avoid any device which might work loose or produce noises. The cars shall be provided with approved spring buffers of such design that there shall be absolutely no jerking between the separate units upon the starting of the train. All designs for cars, trucks, and devices shall be submitted to and approved by the railroad company.

The essential characteristic of this railroad will be its speed, wherefore the rolling stock shall be so designed and constructed that high speeds shall be attained and maintained with the utmost comfort and safety to the traveling public, and with a minimum possible cost of maintenance for wear and tear upon the equipment. The electrical equipment provided shall be such that the train units can be operated from any platform of any motor car in any train unit.

All intermediate or trail cars (cars not supplied with motors, as herein provided), shall be wired and supplied with connection plugs and devices to enable all motor cars to be connected, and the train operated from any platform of any motor car regardless of its position in any train unit.

The length of each of the cars shall be such that the clear inside length shall not be less than forty-five feet. The seats shall be arranged in such manner as to provide a maximum carrying capacity per car and produce the utmost comfort to the traveling public, and the cars shall be of a width, not less than eight feet six inches, inside dimensions, as will most facilitate the passage up and down the aisles. The design, material, and general arrangement of the inside of the car, including the distribution of lights therein, as well as the design and arrangement of the outside of the car shall be subject to the approval of the railroad company.

As the element of wind resistance at the speeds which will be attained in the operation of this railroad upon the schedules as provided, will be an important consideration in the power required to operate the trains, the contractor shall adopt such a design and construction as will, without rendering the cars impracticable or objectionable to be used in connection with standard cars of possible connecting railroads, or of operating upon the tracks of other railroads, or without causing any discomfort or risk to the traveling public, produce the lowest amount of resistance. Such designs shall be subject to the approval of the railroad company.

Generating plant.— The sizes and designs of the steam generators, prime movers and electric generators used in any of the stations of this company shall be subject to the approval of the railroad company.

The main generating station shall be of such design and construction, and shall be supplied with such apparatus as will produce results equal to the best results now obtained in the costs of energy per kilowatt hour.

The railroad company reserves the right herein to especially order the contractor to install steam turbines as the prime movers, should it finally conclude to do so upon the more mature investigation of the details of such machines, and, in the event of the railroad company so ordering, the contractor shall install such turbines as may be directed. The main station shall have a capacity of not less than 12,000 kilowatts, with an additional overload capacity, for a period of time not exceeding two hours, of 25 per cent.

All of the steam generators shall be the latest and most approved water-tube boilers. The plant shall be divided into such a number of units as will produce a minimum cost of production when the items of interest, maintenance, or depreciation and operation are all considered together.

The condensers shall be of the surface condenser types.

The generating stations throughout shall be equipped with such devices as superheaters, fuel economizers, feed-water heaters, etc., as will produce the largest quantity of energy at the switchboard per pound of coal consumed.

All bends or curves in the steam or water-piping systems shall be long radii curves and all such bends shall be of copper piping.

All steam and hot-water pipes shall be covered with the most approved and substantial heat insulation.

The main steam and main water lines of piping shall be in duplicate with connections from each line to the boilers, pumps, prime movers, etc.

All steam and hot-water pipe lines shall be provided with the latest

expansion devices for taking up the variations in length due to changes of temperature.

Each of the substations, which shall be located and so interconnected as to best subserve the condition of reliability of operation, and reduce to a minimum liability of shut-down, shall be supplied with accumulators of the best make, and of capacity sufficient to take the peak of the load curves.

Water, water-ways, docks, etc.— The main power station, as herein provided for, shall be installed at such a point where there will be ample water for use in the boilers, as well as for the purpose of condensing the steam, after it shall have been used in steam prime movers. The stations shall be so located that the coal and other fuel required for the generation of the steam can be brought up to the company's property and wharves or docks, to be erected by the contractor, on barges or vessels without the necessity of trans-shipping or lightering or reloading such barges or vessels in any harbor or water-way in or about New York City or Westchester County.

If necessary, the contractor will dredge a channel sufficiently deep to enable any and all barges or vessels to be brought up to and anchored alongside the company's property where the main power-house or generating station will be located.

All necessary dredging, construction of docks, etc., required for the provision of the water-ways and unloading facilities, as herein indicated, shall be done by the contractor at his expense and without any extra cost to the railroad company.

Transmitting circuits.— The design of the transmitting circuits shall be such that the maximum loss, under maximum average conditions, between the main generating station and any substation shall not be more than 5 per cent. The loss between any of the substations and any point along the line of the road where current may be required, shall be such that the loss, under maximum average conditions, shall not be more than 10 per cent.

The installation shall provide for not less than 575, nor more than 630 volts, at the car-collecting device at any point along the line under maximum average conditions. The third-rail installation shall be of the latest design and construction and of such kind as will, as far as possible, eliminate the element of liability of accident to persons on the roadway. The design and construction of the third rail shall be such as will, within reasonable limits, avoid all possibility of shut down due to sleet, frost or snow storms. The design and construction of the third rail shall be subject to the approval of the railroad company. The contractor shall erect along the line of the roadway at such points as

shall be designated by the railroad company electric lights of such kind and power as shall be designated by the railroad company. The total number of such lights shall not be more than 500 lights.

The design and construction of the third rail or circuits conveying energy to the car contacts or car current collectors, shall be such that the collectors or contacts of each motor car of each train unit will be in contact with the third rail or energy-conveying circuit no matter where the car may be on any part of the main or branch lines in or about the termini or stations, or in or about the car yards or storage yards, etc., or in crossing over or passing across any switch, cross-over or other special work. There shall be no "dead" places or places where a car or each motor car of a train unit cannot be moved with its own motors taking current from the line.

Buildings for power-houses, carhouses, and stations, etc.— The buildings for all power-houses, carhouses, substations, car-barns, machine shops, paint and repair shops, and express stations (wherever buildings shall be required for express stations), shall be the most substantial brick or stone masonry structures. The brick or stone in all cases shall be laid with a mortar composed of Portland cement in the proportion of one part of cement to three parts of sand. The brick or stone used shall be in all cases of the best quality brick or stone. As already provided, the buildings for the power-houses, carhouses, and machine shops shall be constructed to provide for the installation of traveling cranes of ample capacity to handle the heaviest piece of machinery or equipment which might ever be required in said buildings, as herein specified.

All power-houses, power-stations, carhouses, substations, car-barns, machine, paint and repair shops, and express stations, shall be absolutely fire-proof.

Express and freight cars.— The contractor shall provide, in addition to the seventy-five passenger cars, herein provided, ten closed boxcars, to be used for the transportation of freight, express, etc. Five of these ten cars shall be equipped with four motors each, which motors shall be identical with those used for the passenger equipment.

The painting and outside finish of these cars shall be like that of the passenger cars. The interior of these cars shall be neatly finished and such partitions and lights provided as shall be directed by the railroad company. The contractor shall submit the design of these cars to the railroad company and receive the approval of such design before he shall adopt any car.

The inside dimensions of the express and freight cars shall be not less than forty-five (45) feet in length by eight (8) feet six (6) inches in width by nine (9) feet high at the lowest point.

All cars provided by the contractor for this equipment shall be so designed as to permit of their running safely over any and all parts of the tracks of the Rapid Transit Subway Construction Company now being erected in the city of New York.

Car signals and lights.— Each of the cars of this company shall be provided with proper receptacles for the reception of marker or indicator lamps at each end of the car. Each of the cars shall be provided with an electric headlight of the latest and most apporved design and manufacture; each car shall also be provided with complete equipments of indicator lamps and day signals or markers of the latest, most approved design and manufacture.

7. Stations.

The contractor shall provide in all, including the terminals, twenty-four stations. Twenty-two of the twenty-four stations shall be located on the main line, at the points shown on Exhibit No. 1. The remaining two stations shall be located on the branch line at points shown on Exhibit No. 1. The station at the end of the branch line shall be a brick structure located and designed to directly connect with a ferry landing at Clason's Point, that is, the ferry landing and station platforms shall join. The terminal stations shall be adequate, and shall be so designed and equipped as to comfortably provide, not only for the passenger traffic, estimated to be about 50,000 passengers per day, with a maximum of 10,000 per hour, but also an express and parcel business. There shall be provided at some place, subject to the approval of the railroad company, in and about the terminal stations, properly designed rooms for the receipt and disposal of light freight, parcel, and express shipments. As the plans of the company contemplate the receipt of express parcels from other connecting lines, the contractor shall locate the receiving rooms in such manner that this express and parcel business may be handled in the most expeditious manner. The terminal and express stations shall be substantial masonry, brick, or stone structures, finished in a neat and workmanlike manner, and all the forms of design, construction, and finish shall be subject to the approval of the railroad company.

The station located at or near the southeast corner of Bronx Park, at the junction of the tracks connecting the express tracks of the New York and Port Chester Railroad Company with the tracks of the Rapid Transit Subway Company, shall be a spacious brick or stone structure, of ample capacity to handle the immense traffic and business which will maintain at this station. This station shall be designed and constructed

to provide for a quick, safe, and easy interchange between the express, local, and branch line services.

The intermediate stations along the line of the road shall be so designed as to provide for a minimum number of men in the conduct and operation thereof. The preference of the company is that where the tracks of its road are on an embankment, the stations shall be constructed by building an underground passage at right angles to the line of the road and extending completely across the road. This passage shall be of such width, not less than fifty feet, as will permit the erection of the necessary ticket booths and waiting-rooms therein. The plan of operation contemplates trains running in the same direction on the tracks adjacent to the outside tracks, while trains on the outside tracks shall run in opposite directions, wherefore the designs of the company contemplate two sets of stairways for each station other than the terminal station, and where four tracks are used, each set terminating between those tracks upon which trains are running in the same direction, and coming up on to the platforms between the two tracks on which trains will run in the same direction. The terminal and express stations shall be fire-proof stations throughout. For two-track construction the station or platform shall be between the tracks.

Between each set of tracks upon which trains are running in the same direction as above indicated, there shall be erected platforms of substantial design and construction and of such length as will enable trains of not less than six cars to load and unload from any platform in the train.

The stations and platforms between tracks shall be covered with a roof of such design and construction as will protect the passengers from the elements. The ends of the stations shall be protected by suitable guards. The skeleton of the roofs of the intermediate stations shall be of steel.

Wherever the tracks of the company are beneath the existing street grades, etc., the preference of the company will be for the station design as immediately heretofore provided, with the exception that in the latter case the entire station will be above the roadway and extend across the roadway, and shall be completely enclosed and roofed in to provide proper shelter for the ticket booths, waiting-rooms, etc.

The company will provide for the contractor general designs of the stations as above indicated, which shall be adopted by the contractor.

All stations shall be thoroughly ventilated, lighted, and provided with running water, and such retiring and other apartments as the company may direct, and shall be connected to the nearest sewers in such a manner as to produce the best sanitary results, and in all cases in conformity with any existing local ordinances or regulations.

The local stations, as well as the station along the two-track portion of the road at Clason's Point, need not be masonry structures. If constructed of wood, the construction shall be of the steel-frame type, with an appropriate and substantial wood construction and finish. For two-track construction, the stations shall be erected upon the island platforms between the tracks, and provided with the ticket booths and passage-ways so located as to best provide for the collection of the fares and the safe and rapid handling of the traffic. A general drawing for the two-track stations will be furnished.

All the stations on both the main and the branch line running to Clason's Point shall be located as shown on the plans forming part of this specification, furnished by the railroad company.

Station grounds, approaches, etc.— The contractor shall acquire and deliver to the railroad company sufficient real estate at each station on both sides of the tracks of the railroad company, to provide ample grounds for approaches. Such grounds shall be of ample area, and so divided as to provide for the driving in and out of teams carrying persons and goods.

The vehicular roads for approaches in and about the stations shall all be of the loop form in order to permit the continuous passage of the vehicular traffic. Provision shall be made to enable vehicles carrying express and light freight parcels to drive up to the stations and receive or discharge any goods in a manner which will not, in any manner, interfere with the passenger traffic.

8. General Clauses.

The intention of these specifications is to provide, and the intention of the railroad company is to install and the contractor shall, at his own expense, construct, equip, provide and deliver to the railroad company a railroad of the latest and best type. The essential idea of the construction is to provide:

First. Safety to the public.

Second. Reliability of operation.

Third. High schedule and running speeds.

Fourth. Minimum cost of operation and maintenance.

The essential characteristic of this railroad will be its speed, wherefore all material and workmanship must be of the best class in every respect. Nothing of an untried nature shall be used on this installation without the express permission of the railroad company, which permission shall, in all cases, be given in writing.

The contractor shall at all times conduct the work so that there shall be a minimum of inconvenience to the public, and all the streets and

public places occupied by the contractor shall be cleared of all refuse and rubbish at its own expense as rapidly as possible.

The right is reserved to the railroad company to order the contractor to, at any time, clear away all refuse and rubbish whenever, in the opinion of the railroad company, the public convenience may demand it, or whenever the contractor may not show, in the estimation of the railroad company, due diligence in doing so.

The principal lines and grades will be as shown on the profile which will be part of these specifications.

The railroad company, however, reserves the right to change any line or grade, when, in its opinion, it may be deemed expedient to do so, and the contractor shall adopt any such change. In all cases of a change of line or grade, the contractor shall be reimbursed for any additional expense which he may be put to on account of such change. In case, however, of the change of such lines and grades in such manner as to reduce the amount of work, an amount shall be deducted from the contractor's total consideration. The manner and method of arriving at any determination of any additional consideration or any deduction to be made from the contractor, shall be provided in the contract between the contractor and the railroad company.

The railroad company reserves the right, and the contractor shall agree to the right of the railroad company at all times, to inspect any and all material entering into the construction of this work. Agents of the railroad company shall, at all times, have access to any part of the work or any material used thereon, or in connection therewith, and any imperfect work or material which may be discovered before the final acceptance of the work shall be corrected by the contractor, notwithstanding that it may have been overlooked previously by an inspector.

The contractor shall erect, satisfactory to the railroad company, all necessary conveniences, in conformity with local ordinances and sanitary regulations, properly secluded from public observation, for the use of all laborers and others employed on the work.

In all operations connected with this work, all local and other ordinances of the cities, towns, villages, counties, etc., which shall be operative and valid with respect to this work, must be respected and strictly complied with by the contractor.

If, in the prosecution of this work, any material has been brought on the ground for use in the work or selected for use in the work, which shall have been condemned by the railroad company as unsatisfactory or not in conformity with the specifications, the contractor shall immediately remove such materials from the work, and remedy any such work in such manner as may be directed by the railroad company.

The contractor shall employ none but the most competent, skillful, and faithful men to do the work. Whenever, in the opinion of the railroad company, any man or men employed by the contractor shall be incompetent, or, for any reason, the railroad company shall deem him or them not the proper person or persons to be connected with the work, such man or men shall be discharged from the work, and shall not again be employed on it.

Drawings forming part of these specifications.— The railroad company will furnish to the contractor, as part of these specifications, blueprints marked as Exhibits, as follows:

Exhibit No. 1. General map showing generally the line of the route between the southern terminus and the State line at Port Chester. Also showing the general course of the branch line to the East River.

Exhibit No. 2. Being a set of drawings comprising fourteen sheets in all, showing accurately the proposed route and the right of way real estate, being a strip 100 feet wide, as herein provided, to be acquired by the contractor and delivered to the railroad company, extending from the southern terminus, to the State line at Port Chester; also showing the right of way real estate, the same being also a strip 100 feet wide, to be acquired by the contractor for the railroad company, on the branch line. These maps also show the grade lines and the existing contour or elevation of the ground which will be traversed by the center line of the road. The transit lines and grades shown on these maps must be strictly adhered to by the contractor. Provision for any unforeseen or imperative changes will be made in the contract of which this specification will be a part.

Exhibit No. 3. Continuous plan and profile showing transit lines and gradients, also showing approximate cuts and fills. The railroad company assumes no responsibility for the accuracy of the quantity or quality of the excavations or embankments as shown on Exhibits No. 2 and No. 3.

Exhibit No. 4. General drawings showing concrete spans and concrete subways for crossing public highways as herein provided.

Exhibit No. 5. General drawings showing plan of stations and track platforms for four-track roadway as herein provided.

Exhibit No. 6. General drawings showing plan of station for two-track roadway, as herein provided.

Exhibit No. 7. Drawing showing distance of center of third rail from center between track rails of the Rapid Transit Subway Company system, to guide the contractor in so designing the equipment of the New York and Port Chester Railroad Company, so that its cars can be run from its tracks on to the tracks of the Rapid Transit Subway

system and operated on the Rapid Transit Subway system without altering or changing the car-current collecting devices after leaving the New York and Port Chester tracks. This drawing is only intended as a guide and the contractor must assure himself about the final design adopted by the Rapid Transit Subway Construction Company and the Manhattan Elevated Railroad Company.

Right of way, real estate, etc.— The plans of the railroad company are intended to provide for a right of way one hundred (100) feet wide throughout, and the contractor shall acquire and deliver to the railroad company a right of way 100 feet wide throughout, except in such absolutely necessary instances where a strip 100 feet wide cannot be obtained without ruining valuable residence or other property, in which case a lesser width may be authorized by the railroad company in writing, but in no case shall such width be less than sixty-five feet. In any case where a width less than one hundred (100) feet may be imperative, the contractor shall first obtain the consent in writing of the railroad company for such lesser or decreased width. The contractor shall provide and deliver to the railroad company a right of way extending from the southern terminus of the New York & Portchester Railroad in the Borough of Bronx, to the State line between the States of New York and Connecticut, together with the right of way extending from the East river at or near Clason's Point, for the branch line, to the intersection of said branch line with the main line or lines at or near Bronx Park, all of which is shown on the drawings forming Exhibit No. 2 of this specification. The line and grades shown on Exhibit No. 2 shall be strictly adhered to by the contractor. In all places where are to be located stations, storage yards, car-barns, machine shops, power-houses, substations, and repair shops, the real estate shall be ample for the purposes for which it shall be required. Before commencing the work of construction, the contractor shall prepare a plan showing the width of the proposed right of way for the main and branch lines throughout, together with the dimensions of the real estate for all the additional purposes herein provided. This plan shall be approved by the railroad company in writing.

The contractor shall build, in a most substantial and workmanlike manner, all tracks, pits, and transfer tables which shall be necessary for the purposes of storage yards, repair, and inspection purposes. He shall install in the power-house, substations, and car and repair shops, such traveling and other cranes or devices as may be most applicable for the expeditious and economical inspection, repair, and maintenance of the machinery, cars, motors, or other details of the equipment. All designs for the storage yards, power and carhouses, substations and the

equipment thereof, shall be submitted to and approved by the railroad company.

The contractor shall also provide a place for the storage of coal, where or wherein shall be capacity sufficient for the storage of 10,000 tons of coal.

The boiler-rooms shall be provided with the most modern methods for the measurement of all fuel and water used in the operation of the plant, and the handling of all fuel and ashes shall be done throughout by the use of the most approved machinery now employed for such purposes, the designs for all of which, together with the designs for the arrangement of which shall be submitted to and approved by the railroad company.

The express trains of this railroad will be run on a minimum headway of ten minutes, with a minimum headway of five minutes for the local services, for about four hours of each day. The design of the block signal system must be such, that the express and local services upon the minimum headways, as above stated, can be readily and safely made, without eliminating the automatic features of the block signal system as heretofore stated.

The contractor shall provide the most approved receptacles located over the tops of the boilers, which shall have a capacity for the storage of 4,000 tons of coal. The storage bin shall be provided and connected to proper conveying apparatus for the transportation of the coal from the place of unloading or receiving to the storage bin as provided herein.

Progress, etc.— All materials, appliances, and apparatus required to be provided, and all labor requisite for the proper installation of the same, in accordance with the specifications and plans for the construction and equipment, shall be furnished in ample quantity and time to obviate any delay in any work to be done in the building.

The contractor shall proceed with the different and various portions of the work in the order and at the times necessary and proper for insuring thorough workmanship, due co-operation, between the workmen of the various trades, for obviating delays, and for other legitimate reasons.

All night work or overtime work requisite to meet properly the requirements herein stated as to "progress" and "completion" shall be done by the contractor without cost to the railroad company.

Acceptance.— The railroad may be tendered for acceptance only after the trial tests have been made and completed and after all defects shall have been removed, so as to make the same complete and satisfactory in every respect to the railroad company.

The acceptance or rejection of any one of the separately-specified portions of the work, material, or equipment shall not imply or entail the acceptance or rejection of the remaining portions.

Scope of specifications.— It is the intent and purpose of these specifications to cover and include, under each section, all apparatus, appliances, materials, or labor, necessary to properly install, equip, adjust, and put into the best working condition the respective portions of the railroad and equipment specified. Any apparatus, appliances, material, or labor, not hereinabove specifically mentioned or included, that may be found necessary to complete or perfect any portion of the herein specified railroad or equipment in substantial manner and in compliance with the requirements implied in this specification, shall be furnished by the contractor just as if specifically mentioned in this specification, and without extra cost to the railroad company.

Approval of details.— All details of the construction and installation of machinery and appliances required for the railroad and equipment, or portion thereof, specified or implied in these specifications, shall be subject to the approval of the railroad company in respect to design, proportion, materials, workmanship, finish, setting up, adjustments, etc.

All details pertaining to the construction of machinery, apparatus, or appliances, specified or implied in these specifications, shall be submitted to, and approved by, the railroad company, in writing, before the work of construction is begun.

All details pertaining to the installation thereof shall likewise be submitted, and approved in writing, before the said machinery, apparatus, or appliances are delivered or installed.

Materials.— In the case of all materials or appliances described in the specifications under a specific name, the said name shall be understood as defining and fixing a standard whereby the character and the adequacy of the said material or appliance shall be judged and determined by the railroad company.

All materials or appliances not specifically named in the specifications shall be of the best of their respective kinds, and shall be subject to the approval of the railroad company.

Samples of all materials or appliances, or of finish, requiring to be approved, shall be submitted whenever called for by the railroad company; and no such material or appliance shall be installed until it shall have been duly approved by the railroad company.

The materials and appliances installed shall be in every respect the full equivalent of the samples selected and approved.

Safety appliances and devices.— The contractor shall throughout in the building and equipment of the railroad, install the latest and most

improved devices which will conduce to the safety of the employees of the company who may be required to be on and about the roadway, as well as conduce to the safety of the public. The third rail, the high tension and other transmitting circuits, and all devices connected therewith, shall be covered or protected in a manner so as to best accomplish this object. The contractor shall employ the latest and most improved devices for rendering the cars fire-proof. All fire-proofing designs and devices shall be subject to the approval of the railroad company.

Completion.— The word "completion" shall mean full and exact compliance and conformity with the provisions and requirements, expressed or implied, in these specifications and the plans accompanying and forming part of the same, including all amendments, revisions, corrections, or additions, duly authorized, as provided.

Deputies, etc.— The contractor shall be responsible for any and all parties deputized or employed for furnishing or doing any portion of the equipment or work contracted for.

All concerns, firms, individuals, employed by the contractor must be of good standing and reputation in their respective lines, and must be acceptable to the railroad company.

The said concerns, firms, or individuals, shall be required to comply with all the requirements of the specifications and all general or specific conditions and stipulations of the contract in precisely the same manner and to the same degree that would be required of the contractor himself.

Time of completion.— The contractor is to prosecute the herein-specified work and equipment to completion within the term stated in the contract.

Tests.— When the contractor shall have finished all and singular all of the work and supplied and erected all and singular all material required for the construction and commencement of operation of the railroad, as herein provided, he shall, at his own expense, make a series of trial runs and tests extending over a period of not less than two weeks, which tests shall determine the performance of the individual parts of the installation, such as the boilers, prime movers, electric generators, transmission circuits, track and third rail, car motors, and car equipments, and shall report in detail the results of such tests to the railroad company. The railroad company shall have the right to verify such results, at its own proper cost and expense should it desire to do so, and in such case shall notify the contractor, in writing, within ten days after the receipt of the results, as above provided, of

its intention to so verify, and shall complete its investigations and report its results to the contractor within thirty days after the receipt of the result of the tests from the contractor. Should no notification or protest be given or made to the contractor within ten days after the receipt of the contractor's tests, it shall be construed as an acceptance of the results as satisfactory to the railroad company.

The railroad company reserves the right, and the contractor agrees it shall have the right to have its authorized representatives present at all tests made by the contractor, made either during the construction or upon completion thereof, as provided.

The railroad company shall have the right to test at its own expense, any material entering into the construction, or equipment of this railroad, at any time during the construction or after the completion thereof, and every facility to make any and all tests shall be supplied to the railroad company by the contractor when and as demanded of the contractor by the railroad company.

Drawings and designs to be furnished by the contractor.— The contractor shall prepare at his own cost and expense all detail and other drawings required in connection with the construction and equipment of this railroad, or in connection with any and all detail specifications issued or used in connection with the construction and equipment, and shall also at his own cost and expense, prepare all detail specifications, and the contractor shall, at his own cost and expense, prepare and deliver to the railroad company, at the same time that the results of the tests are delivered to it, one complete original set of tracing drawings, and two sets of blueprints on cloth, showing the final construction as installed of every detail of the railroad, together with all general or assembly drawings thereof as installed. This set of drawings shall include the detail and assembly of each and every highway crossing (including the strain sheets thereof), as well as the detail and assembly of all of the equipment, stations, and other buildings, etc., and the cross sections of the roadway, together with a final set of property maps, equal to or superior to Exhibit No. 2, of this specifications, showing accurately the width of the right of way throughout, and the station grounds, etc., together with all other real estate, water fronts, etc. The object of this clause is to enable the railroad company to possess absolutely accurate records of its property at the time of its acceptance.

Condition of streets and highways.— When the contractor shall have finished his work, all streets, avenues, and public highways crossed by the line of the road shall be left by the contractor in as good condition as he found them. The conditions of the streets, avenues, and

highways at the conclusion of the work by the contractor shall be satisfactory to the local or other authorities having jurisdiction thereover, and all work in connection with the railroad involving the disturbance of any street, avenue, or highway along the line of the road, shall be conducted in accordance with all local ordinances and regulations, and to the satisfaction of the local or other authorities having jurisdiction over such crossings and as herein provided.

Other railroad crossings.— Attention is called to the fact that under the general plans furnished herewith and forming part of this specification, the New York, New Haven and Hartford Railroad Company's tracks will be crossed four times by the line of the New York and Port Chester Railroad. Such crossings must be made by the contractor in such manner as not to disturb the New York, New Haven and Hartford Railroad Company, and in a manner satisfactory to the said New York, New Haven and Hartford Railroad Company.

Attention is also called to the crossing of the Port Morris branch of the New York Central Railroad near One Hundred and Forty-third street, and the Southern boulevard. This crossing must also be made so as not to disturb the operations of the railroad crossed, and in a manner satisfactory to the owners thereof.

Wherever other railroads whose tracks are upon or along public streets or highways are crossed, such crossings are considered simply as highway crossings, and no further notice is taken thereof.

New or additional devices.— When and wherever the railroad company shall order the contractor to install any device not now in use as a recognized standard device, and when and wherever the cost of such device shall be in excess of the cost of the best standard devices now in existence, the contractor shall be reimbursed for such excess cost in a manner to be provided in the contract between the railroad company and the contractor.

Contractor must provide all tools, construction plant, etc.— The contractor shall provide, at his own expense, all tools, implements, and all construction material of whatsoever kind and nature, such as material for temporary or false work, cribbing, staging, centering, casing, and all conveyors, dredges, mixing machines, engines, pumps, derricks, piledrivers, or other appliances requisite for the expeditious construction of the railroad as provided. The contractor shall take all necessary precautions to maintain and protect all property, sewers, trees, and other structures, and shall repair any damage occasioned by his work, and shall provide the necessary watchmen, signal lights at night, and fences, and provide and take such measures as shall be necessary for the protection of persons and property, and shall provide such

temporary street crossings as local and special requirements and conditions may require. The contractor shall assume and be responsible for all losses by fire, water, or other causes, during the construction of the work and until its acceptance by the railroad company.

Cleaning up.— The contractor shall remove all temporary structures, rubbish, and unused material after he shall have completed the work, as herein provided, and place the roadway, stations, and the environs thereof in a neat, clean condition. This cleaning up shall be completed before the commencement of the trial tests, as herein provided.

APPENDIX II.

The following is a list of some articles bearing on the subject of interurban railway work:

Earnings and expenses of electric railways:

Population Carried on Massachusetts Roads.	St. Ry. Journal, May, 1897, page 283.
Financial Results of Interurban Railways near Boston [Higgins].	St. Ry. Journal, Sept., 1398, page 471.
Receipts per Mile of Track.	St. Ry. Journal, April, 1899, page 227.
Surface Railway Operation in Manhattan.	St. Ry. Journal, Feb. 21, 1903, page 293.
Freight Business on Electric Railways [Hawks].	St. Ry. Journal, May 23, 1903, page 771.
Interurban Railway Company, Des Moines, Iowa.	St. Ry. Journal, June 20, 1903, page 896.

Concrete bridge construction:

Concrete Arch Bridge Construction [Douglas].	Engineering News, Aug. 1, 1901.
Concrete Steel Bridges in Porto Rico [Thacher].	Engineering News, Aug. 1, 1901.

Third-rail construction:

Collectors for Heavy Traction [Hanchett].	St. Ry. Journal, July 5, 1902, page 13.
The Electric Third Rail [Potter].	St. Ry. Journal, Aug. 2, 1902, page 150.
Third-Rail Electric Traction in Italy.	St. Ry Journal, Dec. 6, 1902, page 896.
Third-Rail Operation on Aurora, Elgin & Chicago Railway.	St. Ry. Journal, Feb. 14, 1903, page 268.
Protected Third Rail on Wilkesbarre & Hazleton Railway.	St. Ry. Journal, March 7, 1903, page 344; May 16, 1903, page 743.
Wooden Blocks as Insulators for Third Rail on Albany & Hudson Railway [Leavitt].	St. Ry. Journal, April 18, 1903, page 599.
Wooden Blocks as Insulators for Third Rail [Gonzenbach].	St. Ry. Journal, April 25, 1903, page 635.

Train acceleration and braking:

Train Acceleration and Braking [Potter].	St. Ry. Journal, Oct., 1897, page 670.
Rapid Transit Service, Power Consumption [Armstrong].	Trans. A. I. E. E., 1898, page 363; St. Ry. Journal, June, July, Aug., and Sept., 1898, pages 312, 376, 432, 539.
Advantages of Rapid Acceleration [Lundie].	St. Ry. Journal, April, 1899, page 228.
Acceleration of Electric Cars [Morse].	St. Ry. Journal, Feb. 2, 1901, page 171.
Automatic Braking.	Railroad Gazette, Oct. 11, 1901.
Tripper System of Automatic Braking [Neff].	Railroad Gazette, Jan. 24, 1902.
Relation of Energy and Motor Capacity to Schedule Speed in the Moving of Trains by Electricity [Hutchinson].	Trans. A. I. E. E., 1902, page 129; St. Ry. Journal, Feb. 1, 1902, page 157.
Acceleration and Movement of Heavy and High-Speed Electric Trains [Gotshall].	Trans. A. I. E. E., 1902, page 210; St. Ry. Journal, April 5, 1902, page 429.
Method of Ascertaining by Means of a Dynamometer Car the Power Required to Operate the Trains of the N. Y. C. & H. R. R. R. between Mott Haven Junction and Grand Central Station and the Relative Cost of Operation by Steam and Electricity [Arnold].	Trans. A. I. E. E., 1902, page 865; St. Ry. Journal, June 28, 1902, page 809.
Tests on Energy Consumption of Electric Cars in Interurban Service around Detroit.	St. Ry. Journal, Oct. 4, 1902, page 474.
Train Unit Control System of the Berlin Elevated Railway.	St. Ry. Journal, Jan. 5, 1903, page 28.

Train resistance:

Train Resistance [Davis].	St. Ry. Journal, May 3, 1902, page 554.
Mr. Davis' Formula on Train Resistance [Lundie].	St. Ry. Journal, May 3, 1902, page 556.
Mr. Davis' Formula on Train Resistance [Bell].	St. Ry. Journal, May 3, 1902, page 559.
Mr. Davis' Formula on Train Resistance [Willie].	St. Ry. Journal, May 3, 1902, page 560.
Train Resistance [Davis].	St. Ry. Journal, June 7, 1902, page 724.
Results of Tests for Air Resistance on the Berlin-Zossen Experimental High-Speed Line.	St. Ry. Journal, June 7, 1902, page 726.
Train Resistance [Armstrong].	St. Ry. Journal, July 5, 1902, page 21.
Results of the Tests on the Berlin-Zossen Experimental High-Speed Line.	St. Ry. Journal, Aug. 2, 1902, page 145.

Plotting speed-time curves:	
Plotting Speed-Time Curves [Mailloux].	Trans. A. I. E. E., 1902, page 901; St. Ry. Journal, 1902, July 5, page 51; July 26, page 121; Aug. 9, page 199; Aug. 16, page 231; Aug. 23, page 255; Aug. 30, page 275.
Motors and motor rating:	
Selection of Electric Motors for Railway Service [Potter].	Trans. A. I. E. E., 1902, page 169; St. Ry. Journal, April 5, 1902, page 422.
Consideration of the Inertia of the Rotating Parts of a Train [Storer].	Trans. A. I. E. E., 1902, page 165; St. Ry. Journal, April 5, 1902, page 436.
Relation of Energy and Motor Capacity to Schedule Speed in the Moving of Trains by Electricity [Hutchinson].	Trans. A. I. E. E., 1902, page 129; St. Ry. Journal, April 5, 1902, page 437.
Discussion of the Relation of Energy and Motor Capacity to Schedule Speed in Moving Trains by Electricity.	Trans. A. I. E. E., 1902, page 193; St. Ry. Journal, April 19, 1902, page 478.
Stopping time at stations:	
Stopping Time at Stations [Gerry].	Trans. A. I. E. E., 1897, page 353; St. Ry. Journal, Aug., 1897, page 471.
Buildings and equipment:	
Interurban Electric Railway Car Equipment [Potter].	St. Ry. Journal, Oct. 4, 1902, page 514.
Trucks for Interurban Service [Uebelacker].	St. Ry. Journal, Oct. 4, 1902, page 517.
Cars for High-Speed Interurban Service.	St. Ry. Journal, Oct. 4, 1902, page 539.
Modern Switchboard Practice [Davis].	St. Ry. Journal, Nov. 1, 1902, page 751.
Rolling Stock of Manhattan Railway Company.	St. Ry. Journal, Dec. 6, 1902, page 907.
Car-House Construction.	St. Ry. Journal, March 14, 1903, page 408.
Application of electricity to steam railroads:	
N. Y.. N. H. & Hartford Electric Railroading [Heft].	St. Ry. Journal, June, 1897, page 329.
Application of Electricity to Steam Railroads [Heft].	St. Ry. Journal, Nov., 1897, page 777.
Increased Business Due to Changing from Steam to Electric Traction [Heft].	St. Ry. Journal, Aug. 25, 1900, page 786; Sept. 8, 1900, page 857.
Electric Cars on Steam Railroads [Evans].	St. Ry. Journal, June 28, 1902, page 805.
Heavy Electric Traction near Paris.	St. Ry. Journal, Nov. 15, 1902, page 807.

Electric Locomotives on the Western Railway of France.	St. Ry. Journal, Feb. 28, 1903, page 314.
Third Rail on the Baltimore & Ohio Railroad [Young].	St. Ry. Journal, March 14, 1903, page 398.
High-Speed Electric Traction in Germany.	St. Ry. Journal, May 16, 1903, page 736.
Three-Phase Electric Railway at Valtellina.	St. Ry. Journal, May 30, 1903, page 788.

Description of high-speed roads:

Grand Rapids. Holland & Lake Michigan Rapid Railway [Damon & Ray].	St. Ry. Journal, March 15, 1902, page 330.
Grand Rapids, Grand Haven & Muskegon Railway.	St. Ry. Journal, July 5, 1902, page 1.
Motive Power and Rolling Stock of the Detroit United Railway [Farmer].	St. Ry. Journal, Oct. 4, 1902, page 144.
Power Distribution and Operating Points on the Detroit, Ypsilanti, Ann Arbor & Jackson Railway.	St. Ry. Journal, Oct. 4, 1902, page 485.
Aurora, Elgin & Chicago Railway.	St. Ry. Journal, Oct. 4, 1902, page 565.
Electric Road from Fayet to Chamonix.	St. Ry. Journal, Feb. 7, 1903, page 206.
Wilkesbarre & Hazelton Railway.	St. Ry. Journal, March 7, 1903, page 344.
Seattle-Tacoma Interurban Railway.	St. Ry. Journal, May 2, 1903, page 646.
Appleyard Syndicate Interurban System.	St. Ry. Journal, May 16, 1902, page 728; May 23, 1902, page 758.
Lackawanna & Wyoming Valley Railway.	St. Ry. Journal, June 13, 1903, page 864.

Descriptions of elevated and underground railways:

Electrical Equipment of the Manhattan Elevated Railway [Pegram, Baker, Stillwell].	St. Ry. Journal, Jan. 5, 1901, page 1.
Tube Railways in London [McMahon].	St. Ry. Journal, Aug. 16, 1902, page 228.
Metropolitan Railway of Paris.	St. Ry. Journal, Sept. 1, 1903, page 797; Sept. 6, 1902, page 305.
Rolling Stock, Third-Rail Shoe, etc., Manhattan Elevated Railway.	St. Ry. Journal, Dec. 6, 1902, page 907.

Tests of interurban equipment:

Analysis of the Operation of an Interurban Railway.	St. Ry. Journal, May, 1899, page 265.
New York & Port Chester Railway Hearing.	St. Ry. Journal, Jan. 4, 1902, page 45.

Tests of Interurban Cars of Union Traction Company of Indiana [Renshaw].	St. Ry. Journal, Oct. 4, 1902, page 522.
Performance of the Dayton & Troy Electric Railway Power House.	St. Ry. Journal, Feb. 28, 1903, page 320.
Test of Subway Motors.	St. Ry. Journal, March 21, 1903, page 446.

Test of station and equipment:

Rockford, Beloit & Janesville Railway.	St. Ry. Journal, April 25, 1903, page 623.

Miscellaneous:

Graphical Representation of Street Railway Statistics [Gotshall].	St. Ry. Journal, Nov. 1, 1902, page 751.
Specifications for Road Bed and Overhead Construction.	St. Ry. Journal, Nov. 22, 1902, page 841.
Table of Third-Rail Roads.	St. Ry. Journal, July 4, 1903, page 43.

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